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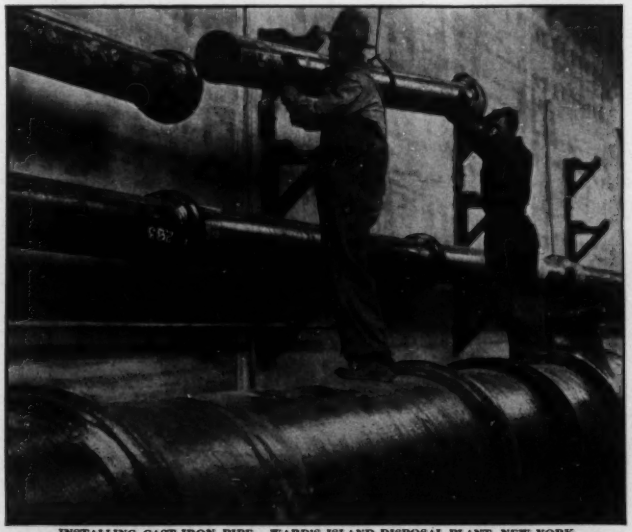

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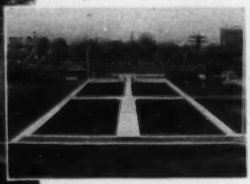

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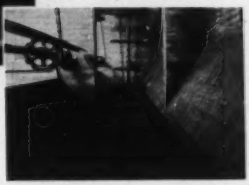

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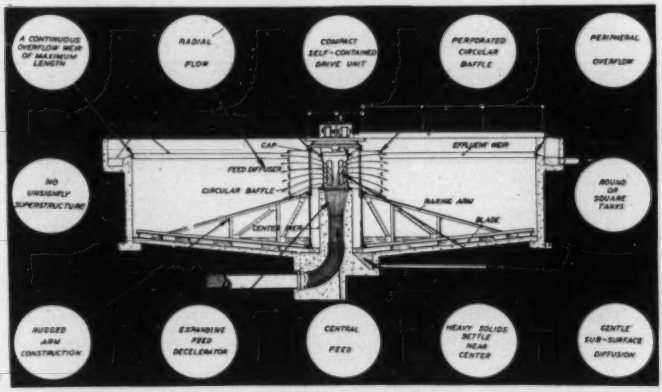

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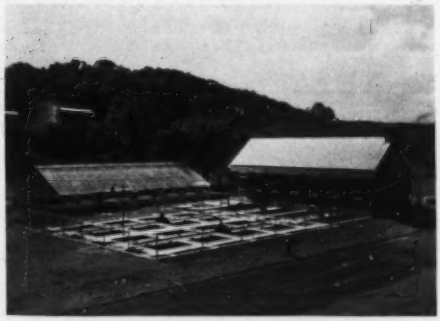

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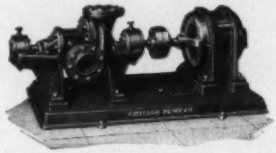

Fig. 1790-1—Screw-Feed Centrifugal Pump

Sanitary District of Chicago North Side Plant	5 Pumps
Lancaster, Pa.	4 Pumps
Herington, Kan.	1 Pump
Marshfield, Wis.	1 Pump
Grays Lake, Ill.	1 Pump

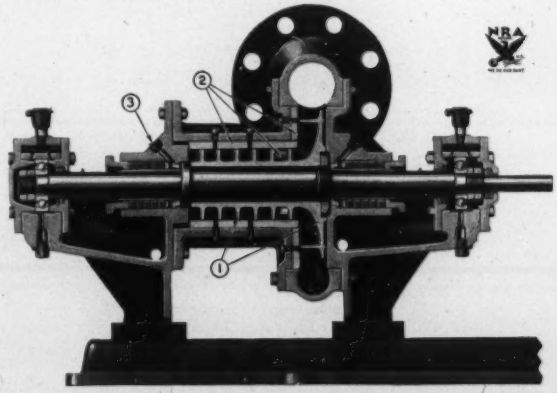

Fig. 1792-1—Cross-Section Screw-Feed Centrifugal Pump

(1) Two-flight screw connects directly with two-blade impeller. Sludge is carried in continuous stream by the screw to the impeller. All solids protruding beyond edges of conveyor are cut up between stellited edges of the screw and stellited flutes (2) in screw housing. (3) Seal water connection.

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Sewage Research

Type and Size of Sprinkling Filter Media*

By Willem Rudolfs, L. R. Setter and H. Heukelekian

Chief, Assistant and Associate, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

We have published several papers[4, 5, 6] on the effect of type of material used for sprinkling filters. The results were obtained from an experimental plant located at Plainfield, N. J.,[4, 5] and dealt with the "working-in" period required for stone, slag and gravel filters; comparative results obtained during winter and summer; and the retention of solids in the different filters.[6] The present paper summarizes the results obtained in the stone, slag, gravel and wire filters over a period of a year and one-half, dealing principally with the purification, load and *B. coli* reduction, while the second part of the paper deals with the effect of two different sizes of stone and slag, larger and smaller than those used in the experiments reported in the first half of the paper.

I. Different Media

Filters.—The experimental filter consisted of a wooden tank made of 2-inch pine boards. The inside diameter of the tank was 11 feet 7 inches and the inside depth 5 feet 6 inches. The tank was divided into four compartments. Each compartment was drained by galvanized pipes at three different depths ($1^1/_2$, $2^1/_2$ and $3^1/_2$ feet) in addition to the drainage at the bottom. The filtering material, consisting of crushed stone, slag and gravel, was hand-picked and in accordance to the specifications that all stone should be $1^1/_2$ to $2^1/_2$ inches in size. Analyses of the stone for size showed that 100 per cent passed $2^1/_2$-inch screens and from 97.5 to 98.5 per cent was retained on a $1^1/_2$-inch screen. The screen filter was made of $^1/_2$-inch galvanized wire mesh laid at $^1/_2$-foot intervals of the depth of the tank.

Flow.—The siphon discharged 180 times per day, delivering 4750 gallons on the filter, or 1.96 million gallons per acre a day. The flow was checked on different occasions by actual measurements. The distribution was determined by the addition of dyes.

Samples.—Samples were collected in pails suspended under the pipes.

* *Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Water & Sewage Research.*

For each sample the sewage from 2 or 3 sprays in succession was collected. Simultaneously, samples were collected at the surface and at the different levels.

Results

The average results for the period from October, 1929, to March, 1931, are given in Tables I and II. These 18 months covered two sloughing periods when the suspended solids discharged were materially greater

TABLE I

AVERAGE RESULTS THROUGH ENTIRE DEPTH OF FILTERS

	Influent	Stone	Slag	Gravel	Wire
Suspended Solids, p. p. m	88	82	74	80	93
Suspended Solids, % Red.	....	7	16	9	−6
B. O. D., p. p. m.	173	86	74	91	121
B. O. D., Red., %	....	51	58	48	30
Diss. Oxygen, % Sat.	40	54	55	51	53
Diss. Oxygen, % Incr.	....	14	15	11	13
Ammonia-N, p. p. m.	29.3	17.8	14.5	18.5	23.9
Ammonia-N, % Red.	....	39	50	37	18
Nitrite-N, p. p. m.	0.07	1.11	1.73	1.18	0.23
Nitrate-N, p. p. m.	0.90	5.93	7.24	4.80	1.12
B. coli, Thousands per Cc.	171	57	39	28	162
B. coli, % Red.	....	66.5	77.2	86.5	5.0

TABLE II

AVERAGE AMMONIA REDUCTION AND NITRITE AND NITRATE PRODUCTION

(P. p. m.)

Level	1½ Ft.	2½ Ft.	3½ Ft.	5½ Ft.
		Ammonia-N Reduction		
Stone	4.1	7.1	10.7	11.5
Slag	4.1	8.5	10.2	14.8
Gravel	3.6	5.2	7.4	10.8
		Nitrite-N		
Stone	0.42	0.71	0.91	1.11
Slag	0.33	0.96	1.30	1.73
Gravel	0.29	0.61	1.03	1.18
		Nitrate-N		
Stone	0.39	2.16	3.76	5.00
Slag	0.40	2.72	3.94	6.30
Gravel	0.20	1.40	2.63	3.86

than those applied. The inclusion of the results obtained during the sloughing periods also affected the B. O. D. results to a lesser extent. To bring out the effect of the sloughing the B. O. D. results have been plotted in Figure 1. After several months of operation the three different filters began to slough simultaneously and recovered at about the same

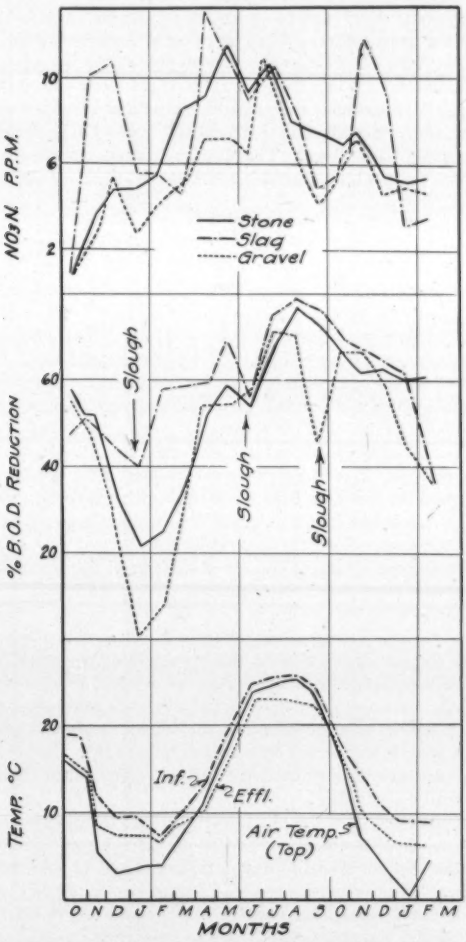

FIG. 1.—Variation of Results and Effects of Sloughing.

time. Sloughing occurred in the spring of 1930 in the stone and slag filters, but not in the gravel filter. The sloughing in the gravel filter took place the following fall. Reductions in suspended solids varied but slightly in the different filters, but there were extreme variations within the individual units. Maximum reduction of suspended solids occurred during winter and summer with occasional actual increases in spring and fall when sloughing took place. The extreme variations observed in suspended solids removal, expressed in percentages, were as follows:

	Maximum Reduction	Maximum Increase
Stone	76	−140
Slag	59	− 87
Gravel	51	− 64

The most extreme variations took place in the stone filter where the solids were temporarily stored and discharged at a rapid rate. Less variation occurred in the slag filter on account of greater quantities of solids being retained which did not unload. The least variation occurred in the gravel filter, due to the fact that somewhat greater quantities of suspended solids were continuously discharged with the effluent. It would appear that the roughness of the slag made for greatest retention of suspended solids, followed by stone and finally by the rather smooth gravel. Correlated with this is the B. O. D. reduction, which shows up most clearly when the sloughing periods are not considered.

The temperature records of the air at the top of the filter, the influent and effluent are also shown in Figure 1. Tests made with HCl fumes which combined with the ammonia given off from the bed to form NH_4Cl showed that the movement of air through the filter varied with the temperature of the air in relation to the sewage temperature. In general, when the air was decidedly warmer than the effluent, aeration was upward and when the air was colder than the effluent the movement was either intermittently downward or upward, but when the air was much colder (Dec.–Jan.) the air movement was in general upward. In general, when the air temperature lines crossed the effluent temperature lines changes in air movement took place.

It can be observed from the plotted results that the percentage B. O. D. reduction varied with the temperature of the sewage. This might be expected since the floral and faunal activities would be influenced by the temperature. Comparing the general trends of the nitrate production curves with the temperature curves it is apparent that nitrification is influenced by the temperature. It is also influenced by solids accumulation, but the general peak of nitrification does not coincide with the maximum temperatures. The peak of nitrification came before the maxi-

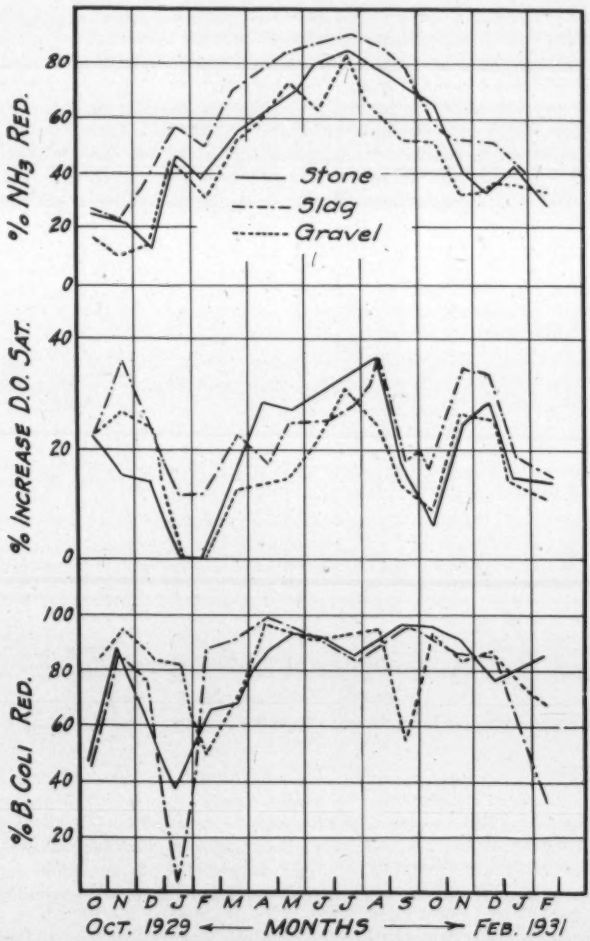

FIG. 2.—Effects of Sloughing on Ammonia and *B. coli* Reduction and Dissolved Oxygen Variations.

mum temperature was reached and shortly after sloughing had taken place. The fact that these two maxima did not coincide was probably due to the load placed upon the bed in the form of large quantities of finely divided suspended solids.

A comparison of the plotted percentages ammonia reduction in the different filters with the observed temperatures shows that the ammonia reduction curves follow the temperature curves closely (Figure 2) in all media. The greatest ammonia reduction took place in the slag filters, followed by the stone and gravel. While during the coldest month of the

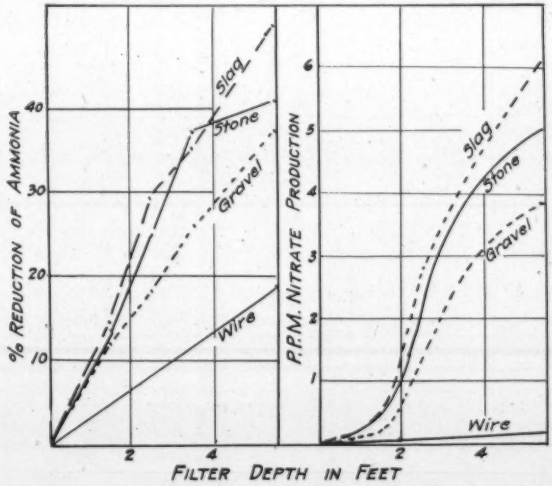

FIG. 3.—Ammonia Reduction and Nitrate Production at Different Levels of Beds

year (Feb.) ammonia reduction was only around 40 per cent, this increased to more than 80 per cent in July.

The percentage oxygen saturation did not seem to be influenced by the temperature, but was decidedly affected by the sloughing periods, so that at the times when B. O. D. and suspended solids reductions were lowest and nitrate production least, the amounts of dissolved oxygen were also low.

B. coli does not appear to be influenced as much by the unloading of the bed as by the temperature factor. In general, greater *B. coli* reduction takes place in summer than in winter.

During the winter period of unloading the average *B. coli* reduction for the three months was, respectively, 56, 59 and 78 per cent for stone, slag and gravel, while for the next winter months, when no sloughing occurred, the results were 55, 68 and 78 per cent, respectively.

The average ammonia reduction and nitrate production over a period of 18 months at the different levels of the beds is shown in Figure 3. The results show that ammonia reduction took place at a nearly constant rate in the slag and gravel filters, but decreased toward the bottom in the stone filter. Nitrate production was persistently greater in the slag filters at all levels of the bed, followed by stone and gravel. The curves tend to indicate that in none of the beds was a maximum efficiency of nitrification reached, although a tendency toward flattening out of the curves, or a decreased rate of nitrification may be observed. The comparative shallowness of the different filter units, with a rate of application of nearly 2 million gallons per acre per day and an influent with a rather high B. O. D., made the tests rather severe. The functions of a trickling filter is in general twofold, namely (1) straining and (2) oxidation of unstable substances in solution and suspension. The straining effect results in the removal of finely divided particles, among which are the bacteria. Since straining takes place in the upper layer of the bed it would ultimately result in an increase of bacteria in this part of the bed if other factors were not present to prevent such increase. Probably one of the most important factors is the protozoa, especially the bacterial feeders. Determinations of the numbers and types of protozoa present at different levels in these filters have shown that the numbers of protozoa increase rapidly from the first 6 inches to the 2–2.5 foot level and decrease rapidly farther down. An example is shown by the following (numbers of organisms per cc.).

Organisms	6-Inch Level	2-Foot Level
Ciliata	144,800	306,825
Mastigophora	7,175	54,050
Sarcodina	700	15,700
Total	152,675	376,575

Of the *Ciliata* the majority were *Opercularia*, namely, 136,150 and 277,000, respectively, at the 6- and 24-inch levels. This organism is an active bacterial feeder and the reduction of bacteria coincides with its increase. With the decrease of reducing bacteria in the level used for straining and the retention of unstable suspended solids, conditions would become more favorable for the oxidizing bacteria if sufficient oxygen is left in the sewage. The results obtained show that, with the exception of the periods of heaviest unloading, sufficient oxygen was taken up by the influent through the spraying into the air and passage through the beds to show a decided

increase in the percentage oxygen saturation in the effluent. The average, maximum and minimum percentage increases in oxygen saturation were as follows:

	Av. % Sat.	Av. % Increase	Max. % Increase	Min. % Increase
Influent	30	..	..	..
Eff. Stone	47	17	37	−2
Eff. Slag	54	24	41	11
Eff. Gravel	49	19	39	0
Eff. Wire	44	14	34	−2

It appears, therefore, that the oxygen saturation is not, as a rule, the limiting factor for oxidation in the filters, but the quantities of suspended solids which reduce the active zone of the filters. With a decrease in sus-

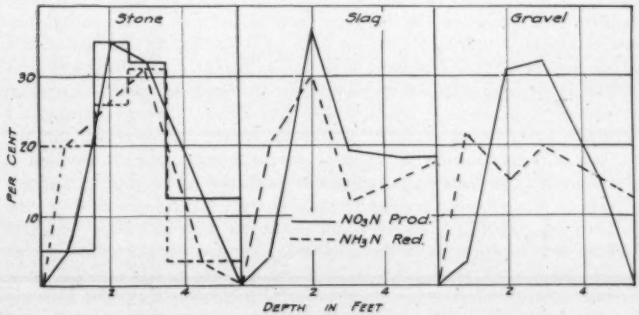

FIG. 4.—Relation Between Rate of Ammonia Reduction and Rate of Nitrate Production.

pended solids the active zone becomes deeper. The decrease in suspended solids causes a decrease in reducing bacteria and reduction in numbers of bacterial feeding protozoa, giving the oxidizing bacteria a chance to multiply and to become most active in that zone of the bed where the least straining takes place. Theoretically, therefore, it could be expected that nitrification would be greater in the lower half of the bed than in the upper half. The width of the oxidation zone would vary with the amounts of suspended material to be removed or, in other words, it would vary with the zone of straining. It has been shown previously[4] that a shifting of the most efficient level occurs gradually and that the zone of straining increases in thickness until unloading begins. When sloughing has taken place the depth of the nitrification zone increases again, with subsequent greater quantities of nitrates in the effluent.

From Figure 3 it is evident that greatest nitrate production took place

in the slag, followed by the stone and the gravel filters. The rate of decrease of ammonia and the rate of increase in nitrates are graphically shown in Figure 4, where the differences in percentages per foot from level to level are given. The curves show clearly that the maximum rates of nitrate production and ammonia reduction take place below the zone of straining. It is evident also that the rate of nitrate production follows the rate of ammonia reduction.

B. O. D. Reduction and Nitrate Production.—The relation between B. O. D. reduction and suspended solids reduction has been shown by Chamberlin[2] for the same filters. Reduction of soluble material such as ammonia should also be related to reduction of B. O. D. and of suspended solids. Since the oxygen demand is reduced biologically and ammonia

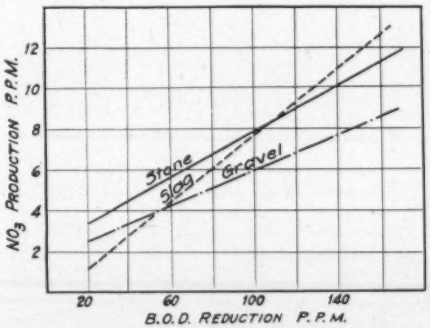

FIG. 5.—Relation Between Nitrate Production and B. O. D. Reduction in Different Filters.

is converted into nitrates it may also be expected that a relation can be demonstrated between nitrate production and B. O. D. reduction. Such a relation has been shown to exist at Baltimore[3] and Chamberlin[2] showed similar results for the stone filter at Plainfield. The relation does not seem to be constant but varies probably with the depth of the bed and also with the type of media. As an illustration the results obtained with the different media after the filters had been "worked in" are graphically shown in Figure 5. In the slag medium nitrate production appeared to be more rapid, in relation to reduction of B. O. D., than either in the stone or gravel filter, but at the lower portion of the curve relatively less nitrate was produced in the slag medium than in either of the others. This would seem to indicate that the slag would be less efficient at lower B. O. D. loads but more efficient at higher than either stone or gravel.

Because nitrification is a biological process it can be expected that temperature is an important factor. Plotting all the winter and summer results for the different filters (Figure 6), ammonia reduction and nitrate production, in relation to B. O. D. reduction, were much greater during the summer months than during the winter. The rate of increase in nitrate production in relation to B. O. D. reduction appears to be about 3 times greater in summer than in winter. The lower the B. O. D. reduction the

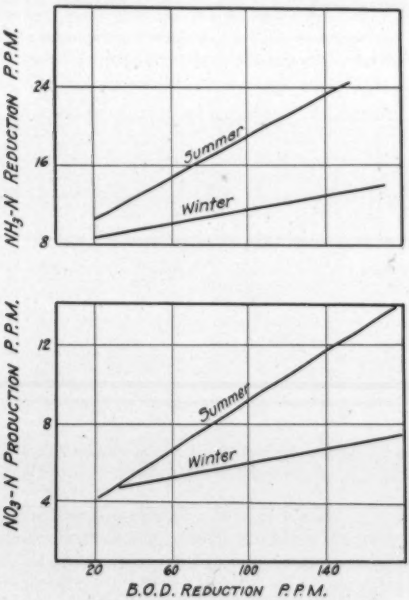

FIG. 6.—Effect of Temperature on Relation Between Nitrate Production and B. O. D. Reduction.

less important the temperature factor becomes. Naturally, the same holds for ammonia reduction.

If the analyses made during the different sloughing periods are excluded, the results indicate that an increased filter load results in production of a poorer effluent from the different filters (Figure 7). This holds for the different media in general, but the impairment of effluent was lower

in the slag filter than in the others. With the increased B. O. D. load, however, the relative efficiency of the filters increased.

B. Coli Reduction.—The average percentage *B. coli* reduction over the entire period was about the same in the three different media, varying between 75 and 81 per cent. The greatest *B. coli* reduction took place in the upper half of the bed, varying from 64 per cent in the gravel to 74 per cent in the crushed stone. Reduction in *B. coli* was greater in summer than in the winter, as shown by the following results:

	Stone	Slag	Gravel
	Reduction of *B. coli*, Per Cent		
Winter	64	75	75
Summer	86	88	91

This difference was due to the difference in behavior of the upper part of the filter. During the winter the straining activities continue but biological activities are reduced. Since the bacteria feeding protozoa are important in *B. coli* reduction and the activity of these organisms is retarded in cold weather, it can be expected that the *B. coli* are reduced during the winter to a less extent. The most abundant active bacteria feeder, *Cpercularia*, occurs in greatest numbers in the upper part of the bed and it may be assumed that the bacteria which are strained out in the upper section of the bed provide an abundance of food and subsequently the numbers are lower in the effluent. The oxidizing bacteria are present in largest numbers in the lower half of the bed where far less bacteria-consuming protozoa interfere with their work.

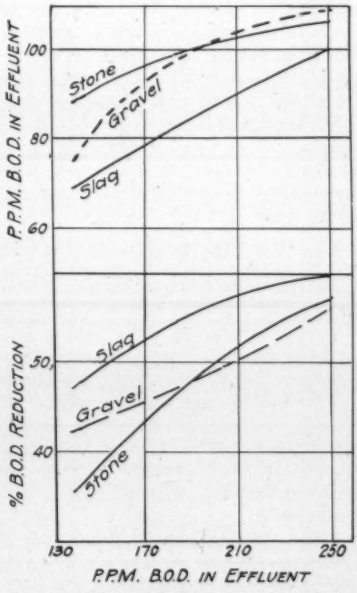

FIG. 7.—Effect of B. O. D. Load on Filter Efficiency.

Unloading.—Unloading or "sloughing" of the different filters varied. The amount of dry suspended solids retained by the slag filter after a period of 18 months was about $2^1/_2$ times as great as that retained by the

stone and gravel filters. The following results show the average amounts of solids retained, and ash and nitrogen content of the sludge per cubic foot of filter material in the different filters:

	Grams Dry Solids	Ash Per Cent	Grams Nitrogen
Stone	137	29.8	6.97
Slag	315	42.0	12.33
Gravel	122	27.0	6.76

Analyses of material present at different levels showed that more inert material was persistently present in the material from the slag filter. Such material increased rapidly toward the bottom, indicating that some of the slag had disintegrated. The putrescibility of the material in the slag was also greater, amounting to a population equivalent of 107 people for the filter as compared with 41 in the stone and 66 in the gravel. On the basis of an acre bed, 6 ft. deep, the results would be a population equivalent of 16,900, 44,200 and 27,250 for stone, slag and gravel, respectively. The results, in general, indicate that slag retains sludge to a greater extent than the other media and consequently would be subject to pooling and clogging sooner, or, in other words, with equal loads the slag filter would have to be cleaned after a much shorter period of operation than the other media used.

II. Effect of Size of Media on Purification

Filters.—The same experimental filter units were used as previously, but the filter media were crushed stone and slag of two different sizes. The variations in size of the stone and slag used were as follows:

a. Crushed stone and slag ranging in size from $^3/_4$ to $1^1/_2$ inch, with less than 2% materials which would pass through a $^3/_4$-inch mesh sieve.

b. Crushed stone and slag ranging in size from 2 to 3 inches, with less than 2% materials which would pass through a 2-inch sieve. The larger size stone was all hand picked for uniformity. The crushed stone was obtained from the Bound Brook Crushed Stone Company, and the slag was donated by the Duquesne Slag Products Company of Philadelphia, Pennsylvania.

Flow.—During 1929 and 1930 the average rate of application was 1.96 million gallons per acre per day, while during 1931 and 1932 the average yearly rate of application was 1.73 mil. gal. per acre per day. The average daily variation of the rates of application were from 1.56 in November to 1.85 mil. gal. per acre per day in April. The average spraying time per siphon discharge was 6 min. and 25 sec. with 180.7 discharges per day.

Samples.—The samples were collected as previously described.

Results

Chemical.—Analyses of the influent and effluent are given in Table III. A perusal of the table shows that the small sizes of stone and slag

TABLE III

AVERAGE RESULTS FOR YEAR 1931–1932

	Influent	Stone		Slag	
		Small	Large	Small	Large
Dissolved Oxygen, % Sat.	17.1	40.6	39.4	46.2	42.5
B. O. D., p. p. m.	186	67	100	68	95
B. O. D., % Red.	...	64.0	46.2	63.3	48.6
Suspended Solids	162	97	124	92	102
Suspended Solids, % Red.	...	40.0	23.5	43.0	37.0
Ammonia-N, p. p. m.	38.7	8.43	18.8	11.5	18.7
Ammonia-N, % Red.	...	78.1	51.3	70.3	51.3
Nitrite-N, p. p. m.	0.026	0.55	0.68	0.63	0.77
Nitrate-N, p. p. m.	0.67	12.6	10.25	12.47	9.8

were about equal in purification and the large stone and slag sizes were very close together in efficiency. However, the difference between the

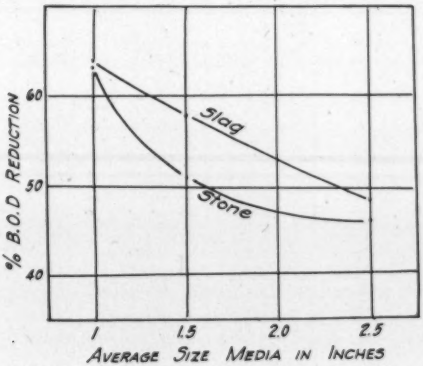

FIG. 8.—Relation of Size of Filter Media and B. O. D. Reduction

fine and coarse media was quite marked. Unfortunately, no direct comparison of these results can be made with those obtained during the previous year with medium slag and stone because the flow of the plant had decreased, as evidenced by a decrease in the rate of application of 12 per cent; moreover the sewage contained nearly 100 per cent more suspended solids. The B. O. D. of the sewage applied was only slightly higher but

the ammonia had increased by 24 per cent. On account of the greater amounts of suspended solids the percentage reduction was less in the small and large media, although the amount of suspended solids retained in the beds was about equal in the large media as compared with the middle-sized stone and slag and considerably more in the fine material used. Figure 8 shows the relation of size of medium and B. O. D. reduction, although the results as stated above are not directly comparable in every respect.

Chemical results obtained from samples collected at different levels of the beds were averaged for the year. The crushed stone and slag filters were nearly alike in performance, but there were differences between the coarse and fine material as illustrated by the results plotted in Figure 9. Ammonia reduction in the small stone was persistently greater than in the

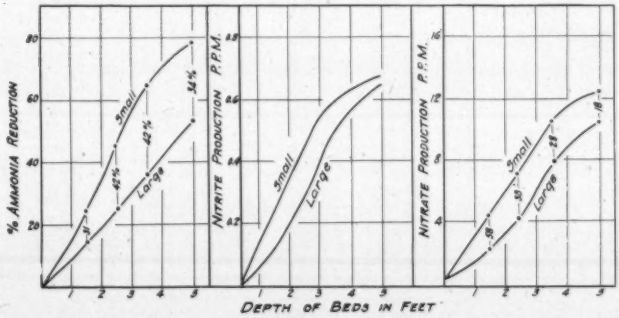

FIG. 9.—Effect of Small and Large Stone on Ammonia Reduction and Nitrate Production.

large stone. The differences in the percentage reduction increased until the 3-foot level was reached, but farther downward the percentage differences decreased. Nitrate formation was persistently greater in the small stone at all levels of the bed, but the percentage differences became gradually less.

A comparison of the monthly dissolved oxygen saturation figures or the percentage increase in saturation of the effluent with the average monthly B. O. D. reductions does not show any direct relations. The dissolved oxygen in the effluent may increase very materially without being reflected in the B. O. D. reduction. In all cases the dissolved oxygen saturation varied between the extremes of 30 to 70 per cent, while the great majority of the results fall between 40 to 50 per cent saturation. Evidently lack of oxygen was not the cause for the relatively low B. O. D. reductions.

Temperature differences between the influent and effluent amounted on the average to 2.3° C., while the average difference in air temperature at the top and bottom of the filters was 3.2° C. The monthly maximum, minimum and the yearly average temperatures were as follows:

	Maximum	Minimum	Average
Air Top, °C.	28.7	5.7	14.6
Air Bottom, °C.	19.0	4.3	11.4
Influent, °C.	23.0	9.4	15.4
Effluent, °C.	19.3	7.0	13.1

With the exception of one month the average air temperature was always higher at the top than at the bottom of the filters. The great majority of the individual readings showed that the effluent temperature was higher than the air temperature at the bottom. As previously described[4] the changes in temperature indicate the direction of air movement through the filters.

B. Coli.—The results of samples from the different media show considerable fluctuation in the number of organisms remaining in the effluent. The average results for the year show that more organisms remained in the effluent from the large stone and slag than in the effluents of smaller material. In comparing the slag with the stone media both the large and small sizes show a slight advantage in favor of the slag. However, the percentage removals were rather high in all cases and compare favorably with the results obtained previously with the different materials of medium size.

TABLE IV

ARITHMETIC AND GEOMETRIC AVERAGES OF *B. coli*

	Numbers per Cc.		Per Cent Reduction	
	Arithmetic	Geometric	Arithmetic	Geometric
Influent	107,000	138,000	..	..
Small Stone	14,600	9,550	86	93
Large Stone	20,000	10,000	81	93
Small Slag	8,600	5,370	92	95.5
Large Slag	11,000	11,500	90	92

It was considered of interest to calculate geometric as well as arithmetic averages of the results. For geometric averages the logarithms of the numbers are averaged. The results are shown in Table IV. The geometric method of averaging obliterates the differences found by the arithmetic method and somewhat increases the percentage removals. If this method is used the different media appeared to be practically equal in *B. coli* removals.

Discussion

In an effort to determine the relation, if any, between the B. O. D. load and the relative efficiencies of the bed, the individual analyses were grouped

TABLE V

B. O. D. REDUCTION WITH DIFFERENT LOADS APPLIED

B. O. D. Applied P. p. m.	Influent Aver. P. p. m.	Stone Effluent Aver. P. p. m.	Stone Effluent Red. P. p. m.	Stone Effluent Red. %	Slag Effluent Aver. P. p. m.	Slag Effluent Red. P. p. m.	Slag Effluent Red. %
Above 200							
Fine	238	63	175	74.0	63	175	74
Coarse	238	104	134	56.2	112	116	53
From 125–200							
Fine	158	60	98	62.0	52	86	67
Coarse	158	75	83	52.5	85	73	46
Below 125							
Fine	81	38	43	53.0	35	46	57
Coarse	81	46	35	43.0	46	35	43

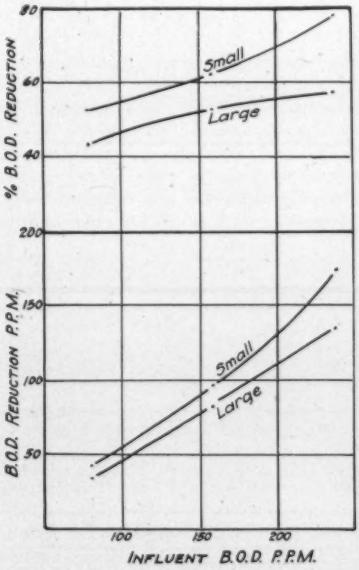

FIG. 10.—B. O. D. Reduction with Different Loads with Small and Large Media.

on the basis of the strength of the influent. In order to obtain a picture as clear as possible, the samples taken during the sloughing periods were eliminated, although the inclusion of these results did not alter the relative relationships. On the basis of the former results, obtained with the medium sized stone and slag, it was expected that with increasing B. O. D. loads the several filter units would produce a somewhat poorer effluent, but a greater percentage reduction or greater filter efficiency. A perusal of the results (Table V) shows this to be the case. The performance of the fine stone and slag was practically alike, but the coarse slag seemed to be slightly less efficient at the higher loads. The difference between fine and coarse stone is graphically shown in Figure 10. With the increase in load the difference in reduction of B. O. D. (p. p. m.) between the coarse and fine stone has a tendency to become gradually greater. These differences are not sufficient to indicate how much deeper, if any, a bed of

coarse stone should be to obtain the same efficiency of B. O. D. reduction as a bed filled with fine stone.

Since B. O. D. reduction is only a part of the function of the filter bed, it is of interest to inquire whether the relative rate of decrease in nitrate formation as noted above might indicate how much deeper a coarse filter should be in order to obtain nitrification equal to that found in the lowest level of the fine stone. When the differences in nitrification are plotted (Figure 11) the indications are that a filter with $2^1/_2$-inch stone would have to be several feet deeper in order to produce nitrification equal to a filter with 1-inch stone. It may be assumed that the surface of the film has a relation to the amount and possibly the rate of nitrates formed. The surface of the film would vary with the surface of the stone. The surface of the same volume of stone varies with the size. Under ideal conditions the surface area of 1-inch stone would be about 2.5 times greater than that

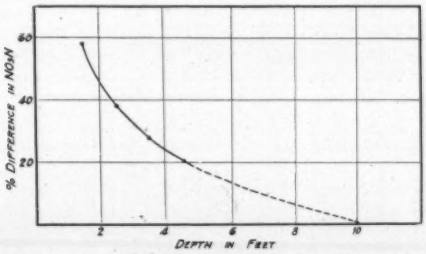

FIG. 11.—Percentage Differences in Nitrates Formed in Small and Large Stone Filters.

of 2.5 inch stone, but since the points of contact of the small stone would increase, making the size of the voids smaller, the practical stone surface available in the small stone bed would be less than the actual surface area of the stone. Therefore part of the increase in area is not available for film. The results in Figure 11 indicate the possible required depth for coarse stone as compared with fine material. Under theoretical conditions the filter would have to be 12.5 feet deep; extending the curve obtained from the results, a filter of about 10 ft. depth is required to produce results similar to those obtained in a filter with fine stone.

B. O. D. reduction is related to the removal of suspended solids. Since soluble products which have a definite B. O. D. are readily oxidized in the filter a correlation between one of the biological end products (nitrates) and the gross reduction of B. O. D. might be demonstrated. The average results obtained from the coarse and also from the fine filters were grouped

into two periods, namely, the months before and after sloughing, leaving out those results obtained during the sloughing period. The plotted results are shown in Figure 12. It is apparent that after sloughing a greater degree of nitrification was obtained with equal B. O. D. reduction than before the sloughing period. The differences were much greater in the fine materials than in the coarse stone and slag. It has been shown several times previously that nitrification increases after sloughing. This was

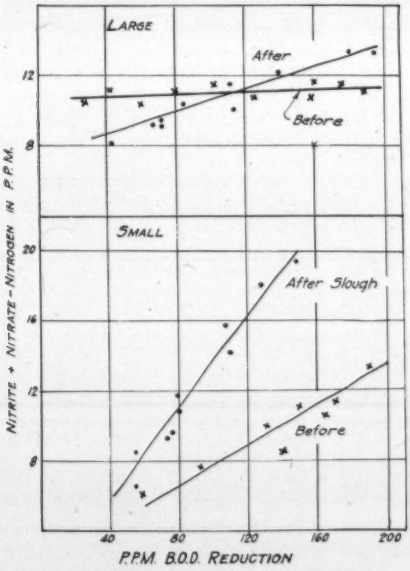

FIG. 12.—Relation Between B.O.D. Reduction and Nitrification Before and After Sloughing.

attributed directly to the accumulation of suspended solids. It appears now that under certain conditions (solids accumulation and coarse stone, *i. e.*, rather small surface area for filter) B. O. D. reduction may vary widely without affecting nitrate formation, whereas under other conditions (less solids accumulation and fine stone) nitrification is greatly increased. It appears also that with equal B. O. D. reduction the rate of nitrification may be either greatly increased or decreased. It seems, therefore, that the quantities of suspended solids placed on the bed, or rather those retained

in the bed, are indirectly responsible for the poorer performance, because the accumulation of the solids reduces the active film area, which in turn produces poorer results. By analogy, similar results are obtained when insufficient active sludge is retained in an activated sludge aeration tank. This in turn indicates that with little solids accumulation the B. O. D. load determines the efficiency of the filter, and that ordinarily both factors must be taken into consideration.

In Figure 6 the differences in efficiency between summer and winter operation are demonstrated. A comparison of this figure with Figure 12 shows strikingly that the effect of an increase in temperature is similar to the effect of an increase in surface area. In the case of the results plotted in Figure 12, temperature effects were eliminated because sloughing occurred in January and February and the time of running the filters before and after sloughing was nearly equal.

The relation between ammonia reduction and nitrate production in the stone, slag and gravel filters is clearly shown in Figure 4. However, a part of the ammonia is not converted into nitrates and is not found in the effluent. As a matter of fact, only 35.8 per cent of the ammonia in the gravel, 37.6 per cent in slag and 43.2 per cent in the stone was accounted for. Reductions of ammonia in the coarse and fine media were greatest in the upper part of the beds, while nitrate and nitrite formation was greatest in the lower half of the beds. The total amounts of ammonia which could not be accounted for were as follows:

	Stone		Slag	
	Small	Large	Small	Large
NH_3 Lost, p. p. m.	30.3	19.9	27.2	20.0
$NO_2 + NO_3$ Found, p. p. m.	13.2	10.2	13.1	9.9
NH_3 Lost, %	56.4	48.7	51.8	50.5

Reductions in ammonia, formation of nitrites and nitrates and the actual ammonia lost in p. p. m. and percentages, for the different filters,

TABLE VI

LOSS OF AMMONIA AND NITRIFICATION IN UPPER AND LOWER PARTS OF BEDS

		0–2.5 Ft.	2.5–5.0 Ft.
Small Stone	NH_3 Red., p. p. m.	17.3	13.0
	$NO_2 + NO_3$ Prod., p. p. m.	6.7	6.6
	% of Total NH_3 Lost	35.0	21.2
Large Stone	NH_3 Red., p. p. m.	10.1	9.8
	$NO_2 + NO_3$ Prod., p. p. m.	4.0	6.2
	% of Total NH_3 Lost	30.6	18.1
Small Slag	NH_3 Red., p. p. m.	15.0	12.2
	$NO_2 + NO_3$ Prod., p. p. m.	4.2	8.2
	% of Total NH_3 Lost	39.7	14.7
Large Slag	NH_3 Red., p. p. m.	12.7	7.3
	$NO_2 + NO_3$ Prod., p. p. m.	4.3	5.6
	% of Total NH_3 Lost	41.9	8.5

are shown in Table VI. The greater losses of ammonia in the upper part of the bed can be accounted for by the presence there of vastly greater number of bacteria, protozoa and fungi than in the lower part of the bed. In addition, the quantities of suspended solids strained out of the applied sewage were greater in the upper part of the bed. These solids decompose partially and produce ammonia, which cannot be separated by the methods of analyses. This ammonia is either again assimilated or passes to the lower levels, so that the actual re-assimilation must be greater than recorded.

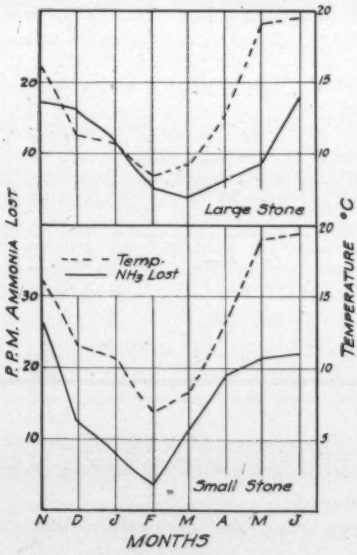

FIG. 13.—Relation Between Temperature and Ammonia Losses.

It should be stated, however, that not all ammonia lost is re-assimilated. A small portion is undoubtedly lost into the air as a gas, because when the experiments were made to determine the direction of air passage through the beds by means of HCl the direction of the travel of the air could readily be detected by the ammonium chloride formed. It has also been observed on the large beds that, upon chlorination of the filters, white clouds formed when the air traveled upward through the beds. We have no evidence to believe that gaseous nitrogen is formed, although such formation may be possible under certain extreme conditions.

The assumption that the ammonia lost is mostly due to re-assimilation may be further indirectly indicated by the direct relation between the temperature of the effluent from the filters and the ammonia not accounted for. The average temperature records for the months November to June, with the average amounts of ammonia lost in the small stone filter, are given as illustrated (Figure 13) for the direct relation. With the decrease in temperature the growth in the film becomes less in quantity and activity. It is rather interesting to note that the effect of temperature on ammonia losses in the large stone lags both when the temperature decreases and increases. If it is correct that the activities of the film are directly related to the surface

area available, or in other words to the mass of the film, we would expect smaller ammonia losses from the large stone filter and also a slower adjustment of the bed to environmental factors.

Summary

Experiments are reported on experimental trickling filters containing $1^1/_2$-inch crushed stone, slag and gravel, and on filters containing 1-inch stone and slag and $2^1/_2$-inch stone and slag. Facilities were available to sample the filters at $1^1/_2$, $2^1/_2$, $3^1/_2$ and 5-foot depths. The experiments lasted about $2^1/_2$ years.

1. The results on the medium size stone, slag and gravel show that the filters received 4750 gallons of sewage per day. Greatest variation in discharges of suspended solids occurred in the stone filter and least in the gravel. The percentage B. O. D., ammonia and *B. coli* reduction, and nitrification, varied with the temperature of the sewage, but the peak of nitrification did not coincide with the maximum temperatures. B. O. D. reduction and nitrification were also influenced by the amounts of suspended solids present in the beds and the quantities discharged. The percentage oxygen saturation was not affected by temperature, but was decidedly affected by sloughing. Protozoa increased rapidly to the 2-foot level, decreasing abruptly thereafter. These variations were related to the reduction in *B. coli*. Unloading varied in the different filters. Slag retained solids to a greater extent than the other media, amounting to about $2^1/_2$ times as much organic matter expressed in population equivalents. Direction of air movement through the beds varied with the changes in the relation between air and sewage temperature.

2. During the studies on the effect of size of media on purification, the volume of sewage applied amounted to 1.73 mil. gal. per acre a day, but the sewage was considerably stronger than when the experiments were made on the different media. The small sizes of stone and slag were about equal in general purification and the large sizes of stone and slag were very close in efficiency. The difference between coarse and fine materials was quite marked. Ammonia and *B. coli* reduction and nitrate formation were persistently greater in the small materials. With increasing B. O. D. loads the several filter units produced a poorer effluent, but a greater percentage reduction. The indications are that with $2^1/_2$-inch stone a filter bed must be several feet deeper than a bed with one-inch stone, to produce equal nitrification. With equal B. O. D. reduction the rate of nitrification may be greatly increased or reduced, depending upon the amounts of suspended materials retained in the beds, while B. O. D. reduction may vary widely without affecting nitrate formation. Temperature effects are very similar to changes in surface area of the material, which in turn affect the surface area of active film available. From 36

to 56 per cent of the total ammonia present in the sewage could not be accounted for and most of this was lost in the upper half of the filters. It is assumed that most of this ammonia is re-assimilated by the mass of bacteria, protozoa and fungi in the upper part of the bed, while a small portion passes off as a gas.

References

[1] Buswell and Strickhouser, *Ill. Water Survey, Bull.* **18** (1923).
[2] Chamberlin, *Proc. N. J. Sewage Works Assoc.*, p. 28 (1931).
[3] Keefer and Regester, *Eng. News Rec.*, **97**, 870 (1926).
[4] Rudolfs, *et al.*, *Annual Rept. Dept. Sewage Disposal*, N. J. Agr. Expt. Sta. (1930 and 1931).
[5] Rudolfs, *Proc. N. J. Sewage Works Assoc.*, p. 46 (1932).
[6] Rudolfs & Chamberlin, *Civ. Eng.*, **3**, 210 (1933).

The Oxygen Demand Test and Its Application to Sewage Treatment*

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One of the principal constituents of polluted water and sewage is organic matter in various complex forms, generally unstable in composition and susceptible to the attack of organisms which feed upon it and break it down into simpler, more stable compounds. Bacteria of many species are largely, if not solely, responsible for this decomposition process. When these biochemical changes occur in the presence of oxygen dissolved in the water, they are generally designated as aerobic, but if they proceed in the absence of oxygen they are called anaerobic. Aerobic decomposition processes are reasonably rapid, direct and result in the formation of inoffensive, stable, mineral compounds. Anaerobic decomposition results in some stable mineral forms and, in addition, other mineral products which contain no oxygen, such as methane and the objectionable hydrogen sulphide. Because of these and other undesirable features of anaerobic decomposition, it is generally advisable in complete sewage purification processes to employ aerobic agencies, which may be done by maintaining a sufficient supply of dissolved oxygen in the liquid at all times to satisfy the requirements of aerobic organisms.

The Course of Oxidation of Organic Matter.—The course of these aerobic fermentative changes occurring in the organic matter of polluted water proceeds in two stages. The first stage results in the reduction of carbonaceous materials and produces chiefly carbon dioxide and water, together with small amounts of organic products or humus.

During the second stage of fermentation the ammonia and humus matters are oxidized to nitrates and small amounts of carbon dioxide. Anaerobic decomposition takes place only during the first stage and then only when the dissolved and other available oxygen has been exhausted; it never recurs in the second step of the fermentation process.

The motivating power in these reactions is the bacteria. Extended observations indicate that these bacteria are only active during the time of their multiplication. When no agencies are present to interfere with their normal reproduction, multiplication of bacterial cells will proceed to a maximum level, depending upon the concentration of available food material, that is, organic pollution. During this multiplication stage, available dissolved oxygen is consumed, but when the upper limit of bacterial concentration is reached, further activity practically ceases and little

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further oxygen is required. If now some natural enemy is introduced that reduces the bacterial concentration, such as bacteria-eating plankton, further multiplication is stimulated to maintain the upper limiting number, and oxidation of the organic matter again proceeds to completion. It would appear then that at least one of the functions of the animal plankton in polluted water is to control the biological balance and stimulate the development of bacterial cells, which in turn is necessary for the natural course of oxidation of organic matter.

The course of this biological or biochemical oxidation proceeds in accordance with a definite law. As enunciated by Adeney (1932),[1] this law states: "The quantities of oxygen consumed and of products formed on the completion of each stage of aerobic fermentation are constant for similar volumes of the same polluted water. This law is applicable to all polluted waters, tidal and nontidal, undergoing purification by bacterial fermentation, provided that the dissolved oxygen be in excess of the fermenting matters." It is upon these principles and this constant relation between dissolved oxygen consumed and oxidizable organic matter that is founded the method of measurement of organic pollution—the familiar biochemical oxygen demand test.

The Biochemical Oxygen Demand Test

The biochemical oxygen demand (B. O. D.) test is a means of determining the amount of organic matter present in a sample by the procedure of measuring the amount of dissolved oxygen used during the oxidation of the organic matter. The biochemical oxygen demand may be defined, therefore, as the milligrams of oxygen per liter of water (parts per million) required for the stabilization of its contained organic matter by aerobic bacterial action. It is most readily determined by the direct estimation, both before and after their incubation for predetermined periods, of the dissolved oxygen contained in suitably prepared subsamples.

The conception of the oxidation theory, the application of these principles to the measurement of organic matter and the development of the test itself are by no means new. These steps, beginning in 1870 with Frankland's work with the British Rivers Pollution Commission, are reviewed by Theriault,[2] who also presents the results of extended studies upon the form of the deoxygenation curve at various temperatures over quite extended periods of time.

The present procedure for performing the biochemical oxygen demand test is described in detail by Theriault[3] and by the Joint B. O. D. Committee of Great Lakes and Ohio River Boards[4] and as approved by the Committee on Methods of Sewage Analysis of the Federation of Sewage Works Associations. Based on many years' experience, these completely

outlined methods, if carefully followed, will enable the analyst to avoid the many pitfalls which formerly beset him in the proper performance of the test. In its essentials, the test consists of the determination of the dissolved oxygen present in each of two duplicate samples, one at the start and the other after incubation, in a tightly stoppered, filled bottle, for a definite period, usually 5 days, at a standard temperature of 20° C. The difference in dissolved oxygen in these two samples is the biochemical oxygen demand of the sample under examination for the incubation period employed. If the sample under examination is a dilution of the original sample of sewage or polluted water, the loss of dissolved oxygen must be multiplied by a factor to express the oxygen demand of the original undiluted sample. The dissolved oxygen used in an interval of five days is commonly named the 5-day demand. Obviously, however, different values of the 5-day demand of any sample would be obtained along various parts of the deoxygenation curve. What is usually meant, therefore, is the 5-day demand during the first five days of the deoxygenation process.

For obtaining comparable measures of deoxygenation rates, certain precautions must be observed in conducting the test. Among these may be mentioned: thoroughly clean glassware, accurately controlled incubation temperature, tightly stoppered bottles, proper neutralization of toxic materials, seeding of samples where such seeding is indicated, and the use of suitable dilution water in cases where dilution is required to maintain aerobic conditions throughout the incubation period.

Advantages of the Oxygen Demand Test.—The test as prescribed has certain advantages over any strictly chemical method such as the permanganate oxygen consumed test, in that it includes all the oxygen used in the conversion or oxidation of organic matter, including nitrogenous and carbonaceous materials, and thereby closely simulates the oxygen requirements of polluted water undergoing purification under natural conditions. The test itself is simple, readily performed, and, with proper technique, produces results having a precision (for the 5-day incubation period at 20° C.) of about 0.1 p. p. m., even when it is necessary to dilute the samples before conducting the test.

Limitations of the Test.—There are, however, inherent limitations of the test which should be clearly recognized. A considerable period of time is required for the completion of the test because of the necessary incubation period. Also, the test is not applicable to liquids which contain toxic substances that inhibit normal biological growth and thereby interfere with the biological oxidation process. Various chemicals and compounds present in the liquid under examination may seriously interfere with the Winkler reagents and produce erroneous results. Modifications of the technique have circumvented these difficulties in the cases of iron salts, nitrites, hypochlorites and sulphites, references to which may be

found in the literature.[3, 5, 6] A further limitation, which necessitates careful manipulation of modifications of the test procedure, results from the inherent low saturation value of dissolved oxygen in water. Therefore, when the sample contains organic matter in excess of its available supply of dissolved oxygen, dilution of the sample is necessary, employing for the purpose oxygen-containing water of suitable characteristics.

Another group of limitations is concerned with the proper interpretation of the analytical results. Time and temperature relationships must be standardized in the laboratory and the determined oxygen demand converted to the natural conditions of time and temperature of the source of the sample itself. For this purpose, reasonably accurate formulae have

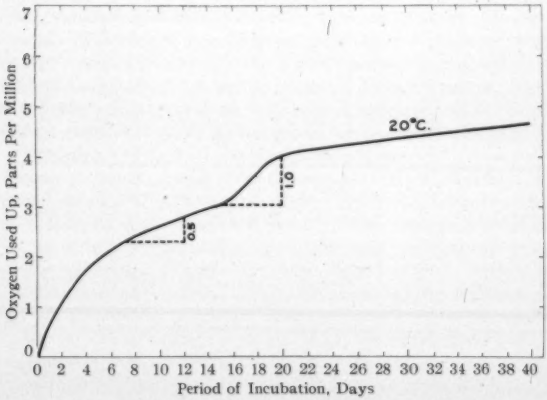

FIG. 1.—The General Course of the Deoxygenation Curve.

been developed through the use of which the oxygen demand of a sample in any interval of time and at any temperature may be calculated from the values obtained under the standardized conditions of the test. A more serious limitation in certain cases, which is discussed in more detail later, is the inability at present to ascertain the state of oxidation of the sample during the period of the test. Still further disturbing factors to the ready interpretation of the results may be the immediate oxygen demand of the sample, a purely chemical demand, or a lag in oxidation at the beginning of the incubation period pending the establishment of normal biological growth.

Interpretation of the Results of the Oxygen Demand Test.—Based on numerous extended observations of the oxygen demand of polluted

waters, the trend of the deoxygenation curve is of the general form shown in the figure, where abscissae are time in days and ordinates are total weights of oxygen used up in corresponding time intervals. Considering only the 20° C. curve, a marked change in direction may be noted about the 14th day which corresponds to the onset of the second stage of oxidation following the practical completion of the first or carbonaceous stage. Justification for the mathematical formulation of the rate of deoxygenation during this first stage has been definitely established and is very useful in the interpretation and practical application of analytical results. Up to the present time the rate of deoxygenation during the second or nitrogenous stage is not so clearly expressed.

The interpretation of the analytical results of the oxygen demand test as pertaining to the first or carbonaceous stage of oxidation is based on the premise, the correctness of which has been amply demonstrated, that: *The date of oxidation at any instant is directly proportional to the amount of organic matter present in the sample.*

From this it naturally follows that: (1) The amount of oxygen required for the stabilization of organic matter is independent of the dilution of the sample; (2) Within wide limits, the oxygen demand of a sample and the rate of dissolved oxygen consumption is independent of the amount of dissolved oxygen present.

Based on this premise, the trend of the oxygen demand curve is defined by the expression:

$$X_t = L\,(1-10^{-kt}) \qquad (1)$$

where X_t = the oxygen demand in t days
L = the total oxygen demand of the first stage
k = the deoxygenation constant = 0.10 at 20° C.

The deoxygenation constant k for any temperature may be computed by the relationship:

$$k_T = k_{20}\,(1.047^{T-20}) \qquad (2)$$

where k_T = the deoxygenation constant at T° C.
k_{20} = the deoxygenation constant at 20° C. = 0.10

The total oxygen demand (of the first stage) L varies in amount with the temperature of the liquid. This relationship is expressed by the equation:

$$L_T = L_{20}\,(0.02T + 0.60) \qquad (3)$$

where L_T = value of L at T° C.
L_{20} = value of L at 20° C.

These formulae are all that are necessary for ordinary computations of the oxygen demand (first stage) of any sample at any period of time at any temperature from the results of a laboratory oxygen demand test. Thus, in the simplest case assuming the 5-day oxygen demand of a sample to be 100 p. p. m. at 20° C., the total demand will be, by Formula (1):

TABLE I

CONVERSION FACTORS FOR OXYGEN DEMAND AT 20° C.

From (Days)	To (Days) (Multiply by) 0.25	0.50	0.75	1	2	3	4	5	6	7	8	9	10	15	20	Per Cent of Total Demand (First Stage)
0.25	1.00	1.94	2.84	3.68	6.60	8.92	10.76	12.22	13.39	14.31	15.04	15.63	16.09	17.31	17.70	5.59
0.50	0.51	1.00	1.46	1.89	3.39	4.59	5.54	6.29	6.89	7.36	7.74	8.04	8.28	8.91	9.10	10.87
0.75	0.35	0.69	1.00	1.30	2.33	3.15	3.80	4.31	4.72	5.05	5.31	5.51	5.67	6.11	6.24	15.86
1	0.27	0.53	0.77	1.00	1.79	2.43	2.93	3.33	3.64	3.89	4.09	4.25	4.38	4.71	4.81	20.57
2	0.15	0.29	0.43	0.56	1.00	1.35	1.63	1.85	2.03	2.17	2.28	2.37	2.44	2.62	2.68	36.90
3	0.11	0.22	0.32	0.41	0.74	1.00	1.21	1.37	1.50	1.61	1.69	1.75	1.80	1.94	1.99	49.88
4	0.09	0.18	0.26	0.34	0.61	0.83	1.00	1.14	1.24	1.33	1.40	1.45	1.50	1.61	1.65	60.19
5	0.08	0.16	0.23	0.30	0.54	0.73	0.88	1.00	1.10	1.17	1.23	1.28	1.32	1.42	1.45	68.38
6	0.07	0.15	0.21	0.27	0.49	0.67	0.80	0.91	1.00	1.07	1.12	1.17	1.20	1.29	1.32	74.88
7	0.07	0.14	0.20	0.26	0.46	0.62	0.75	0.85	0.94	1.00	1.05	1.09	1.12	1.21	1.24	80.05
8	0.07	0.13	0.19	0.24	0.44	0.59	0.72	0.81	0.89	0.95	1.00	1.04	1.07	1.15	1.18	84.15
9	0.06	0.12	0.18	0.24	0.42	0.57	0.69	0.78	0.86	0.92	0.96	1.00	1.03	1.11	1.13	87.41
10	0.06	0.12	0.18	0.23	0.41	0.55	0.67	0.76	0.83	0.89	0.94	0.97	1.00	1.08	1.10	90.00
15	0.06	0.11	0.16	0.21	0.38	0.52	0.62	0.70	0.77	0.83	0.87	0.90	0.93	1.00	1.02	96.84
20	0.06	0.11	0.16	0.21	0.37	0.50	0.61	0.69	0.76	0.81	0.85	0.88	0.91	0.98	1.00	99.00

$$L = \frac{X}{1-10^{-kt}} = \frac{100}{(1-10^{-0.1\times5})} = \frac{100}{0.684} = 146 \text{ p. p. m.}$$

If now we wish to determine the total demand of this same sample at 10° C.; by Formula (3):

$$L_{10} = 146\,(0.02 \times 10 + 0.60)$$
$$= 146 \times 0.8 = 116.8 \text{ p. p. m.}$$

The 5-day demand at this same temperature of 10° C. would be determined by first determining the value of k at this temperature, which, by Formula (2), is:

$$k_{10} = 0.1\,(1.047^{T-20}) = 0.1\,(1.047^{-10}) = 0.063$$

Then, substituting these values of k_{10} and L_{10} in Formula (1):

$$X_{10} = 116.8\,(1-10^{-0.063\times5})$$
$$= 116.8 \times 0.516 = 60.3 \text{ p. p. m.}$$

Tables of the value of the function $(1-10^{-kt})$ for various values of k and of t (2) are helpful in expediting such computations.

It is, of course, possible to compute and tabulate values of the various multiplying factors by means of which the oxygen demand at any time may be converted into the equivalent demand at any other time at the same temperature as in Table I. These factors are simply values of the ratios of the corresponding per cent of the total demand at 20° C. when $k = 0.10$.

Phelps[7] has presented a table of factors for the conversion of the 5-day demand at 20° C. into the demand for any other time and temperature, disregarding the change in total demand at different temperatures as expressed in Formula (3). However, the variation in the oxygen demand value with changes in incubation temperature is not great when the divergences from the standard of 20° C. are small, so that for practical purposes the factors are reasonably accurate.

Where there is a suspected lag effect or an immediate oxygen demand in the incubated sample, the determined 5-day demand figure may lead to erroneous conclusions concerning the true organic matter content. In such instances it is usually advisable to incubate a series of samples for varying time periods, sufficiently extended to furnish at least two observations beyond the time of operation of these interfering factors, and employ the results of these latter observations for computation of the actual oxygen demand. Thus, assuming that a lag in incubated samples should give the following oxygen demands: 1 day, 5 p. p. m.; 3 days, 25 p. p. m.; 5 days, 34.5 p. p. m.; the method of computing the total demand would be, using Formula (1) and employing the increase in demand between the third and fifth day:

$$L = \frac{34.5 - 25}{1-10^{-0.1\times2}} = 27.1 = \begin{cases}\text{the demand from the 3d to the end of} \\ \text{the 1st stage or 20th day}\end{cases}$$

but the 3-day demand is 25, therefore the total is 27.1 + 25 = 52.1 p. p. m. In this case, if the computation had been based on the observed 5-day demand of 34.5 p. p. m., the total demand would have been:

$$L = \frac{34.5}{(1-10^{-0.1 \times 5})} = 50.5$$

a figure which is too low because of the initial lag until the third day. The effect of an initial or immediate oxygen demand result may be circumvented in the same way in the computation of the true total demand. This procedure is also very useful in determining the velocity and trend of the immediate demand reaction, as has been done by Theriault and McNamee in their study of the oxygen demand of sludge.[8]

Applications of the Oxygen Demand Test in Sewage Treatment

The oxygen demand test is widely used for aiding the judgment in sewage disposal operations. It is particularly helpful in estimating the strength of sewage and liquid wastes, is of perhaps less value in accurately gaging the efficiency of the various sewage treatment processes both individually and collectively and is especially serviceable in determining the effect of sewage pollution on receiving streams or other bodies of water.

The Oxygen Demand of Sewage.—The organic content per unit volume of municipal sewage liquors varies between quite wide limits as would be expected, depending upon rates of water consumption and infiltration of ground water, extent and nature of industrial waste contribution, volume of contributed storm water and other factors. Ordinarily, sewages having a total (20-day) demand less than 150 p. p. m. would be considered weak, those ranging from 200 to 250 might be termed average and those above 300 p. p. m. relatively strong. A more consistent gage of organic content for purposes of estimation is the per capita oxygen demand, which is quite uniform regardless of the sewage volume. Extended observations in numerous cities indicate that the following average values of per capita oxygen demand may be expected:

Nature of Sewage	Oxygen Demand, 20-Day, Lb. per Capita Daily
Strictly domestic, dry weather flow	0.16–0.18
Combined, including street wash, moderate trade waste	0.20–0.24
Combined, with higher trade waste content	0.25–0.28
Combined, high trade waste content	0.30–0.50

For computing the per capita oxygen demand of sewage the following formulae apply:

$$P_L = \frac{FX_5}{C81940} = \frac{fX_5}{81940} \qquad (4)$$

$$P_L = \frac{FX_{10}}{C107800} = \frac{fX_{10}}{107800} \qquad (5)$$

where C = contributing population
F = gallons per day of total sewage flow
$f = \frac{F}{C}$ = gallons of sewage per capita daily
X_5, X_{10} = 5-day or 10-day oxygen demand at 20° C. in parts per million
P_L = pounds of oxygen demand per capita daily, based on total oxygen demand at 20° C., first stage

The Oxygen Demand of Sewage Plant Effluents.—The oxygen demand test is frequently employed for evaluation of the efficiency of sewage treatment processes. Inspection of the trend of the deoxygenation curve in the figure will show that considerable caution must be exercised when comparing the oxidation rates of samples, some of which are referred to the time period embracing the transition from the carbonaceous to the nitrogenous stage. In fact, entirely fictitious conclusions may be drawn from such analytical data. Assume that a sample be taken from the effluent of an aeration tank, corresponding to a preliminary treatment period of about 8 to 14 days on the deoxygenation curve. The observed depletion in five days' incubation of such a sample would be comparatively low. Assume a further sample taken from the highly nitrified effluent of a sprinkling filter, corresponding to a section of the deoxygenation curve well beyond the start of nitrogenous oxidation. It is altogether probable that the latter sample will indicate a 5-day demand in excess of that of the former, although purification has certainly progressed much further in the sprinkling filter. This divergence is, of course, greatly magnified when the samples are diluted before incubation and these dilution factors applied to the observed 5-day laboratory results. Until some method is devised for determining the state of oxidation of the sample at the beginning of the incubation period, it will be difficult to estimate to just what stage of the oxygen demand curve the particular sample of partially treated sewage is to be referred. Therefore any comparison of the oxygen demands of effluents of various stages in the treatment process is fraught with difficulties.

It appears, further, that after a period corresponding to about 30 days' incubation the deoxygenation curve is an approximately straight line. Therefore any 5-day demand of a sample beyond this point of oxidation would be constant and, regardless of the extent of additional purification or nitrification, no further improvement would be registered by the oxygen demand test. It follows that the percentage of purification based on 5-day oxygen demand values would also tend to be constant when the definitely nitrified effluent is examined, regardless of the extent of nitrification produced by the treatment process. In fact the degree of purification observed in a representative group of sewage treatment plants was always

about 90 per cent[9] when the 5-day oxygen demand values of the partly nitrified effluents were considered.

The Oxygen Demand of Sludge.—Another useful application of the oxygen demand test would appear to be as an aid in the maintenance of proper aerobic conditions of the sludge, particularly in plants of the activated-sludge type. Insufficient air to aeration tanks, ineffective sludge re-aeration and extended detention in settling tanks, among other factors, affect the smooth working of activated-sludge plants because of the incipient if not actually septic conditions resulting from the unsatisfied oxygen requirements of the sludge. Determinations of the oxygen demand of normal activated-sludge by the method described by Theriault and McNamee[8] indicate that as high as 120 parts per million of oxygen are required per hour in aeration tanks. In re-aeration tanks with concentrated sludge this oxygen requirement may well reach as high as 10 p. p. m. per minute. Failure to supply this amount of oxygen obviously must result in decreased purification efficiency.

It is possible, too, that the clarification and settling qualities of activated sludge are definitely related to its oxygen demand value. Extended observations are essential to establish this point. However, with well conditioned sludge it appears, from the results of unpublished analytical data, that the air requirements for satisfactory operation are closely correlated with the oxygen demand of the raw sewage rather than with the demand of the sludge itself.

Additional Applications of the Oxygen Demand Test in Sewage Treatment.—A further use of the oxygen demand test, not yet generally in vogue, is the determination of the condition of sludge in sludge digestion processes. The primary objective of sludge digestion is the production of stable, well oxidized end products. The oxygen demand test would seem to be a dependable guide to the judgment in determining the proper degree of sludge digestion attained. The test is also recognized as of value in the design of aeration tanks and trickling filters, particularly in plants where strong sewages and industrial wastes are to be handled. The principal function of these devices is the efficient oxidation of organic matter and it would therefore appear sensible to take into account in their design the oxygen-consuming requirements of the liquids to be treated rather than their volumes alone.

The Oxygen Demand in the Receiving Stream.—The oxygen demand test is also of service in estimating the capacity of natural streams for organic pollution, particularly of raw or partially treated sewage, without the creation of septic or anaerobic conditions. In the case of the discharge of highly nitrified sewage plant effluents or toxic industrial wastes, and in the presence of sludge deposits in the stream bed, especially in the case of small streams, caution must be observed in the application of

oxygen demand data. However, in the more general stream pollution case, reasonable estimates of oxygen requirements may be made, knowing the oxygen demand of the contributed polluting material. For purposes of such estimation the following table (Table II) of equivalent values may be useful, giving for each day: (1) the pounds of oxygen required to satisfy one million gallons of sewage having a 5-day demand of 100 parts per million and (2) the cubic feet per second of water saturated with oxygen at 20° C. required to supply the corresponding pounds of required oxygen.

TABLE II

MAXIMUM OXYGEN REQUIREMENTS OF SEWAGE IN STREAMS AT 20° C., IN ABSENCE OF SLUDGE DEPOSITS

Number of Days	Pounds of Oxygen to Satisfy One Million Gallons of Sewage with 5-Day Demand of 100 p. p. m.	Stream Flow in Sec. Ft. of Equivalent Oxygen Content When Saturated with Oxygen at 20° C.
1	250	5.06
2	450	9.13
3	609	12.4
4	733	14.9
5	834	16.9
6	917	18.6
7	976	19.8
8	1026	20.8
9	1068	21.6
10	1101	22.4
20	1209	24.4

As an example of the use of these conversion factors, if a sewage flow of 5 million gallons per day and with a 5-day demand of 200 p. p. m. is to be discharged into a flowing stream saturated with oxygen and not reduce the available oxygen supply below 50 per cent saturation at 20° C. in 2 days, the stream must have a flow of not less than $9.13 \times 5 \times 2 \times 2 = 182.6$ second feet, neglecting the effects of re-aeration, sludge deposits, etc. Conversely, having a stream of known characteristics of oxygen supply and volume of flow, the permissible volume of sewage discharge or the degree of removal of oxygen demand by sewage treatment of a definite sewage volume may be computed. Where re-aeration is to be taken into consideration, the procedures discussed by Streeter are applicable.[10,11]

In conclusion it may be said that while the technique of the oxygen demand test has been quite thoroughly explored, its use in sewage treatment problems must be governed by a definite appreciation of its limitations under specific conditions. Such limitations only indicate the need for the continued accumulation of analytical data and additional research in the endeavor to increase the field of its applications to sanitary problems.

References

[1] W. E. Adeney, "The Biochemical, Biophysical, and Physical Principles Underlying the Self-purification of Crude Sewage Liquors," *The Surveyor*, **82**, 91 (July 29, 1932).

[2] E. J. Theriault, "The Oxygen Demand of Polluted Waters, *U. S. Public Health Bulletin* No. **173** (1927).

[3] E. J. Theriault, "Detailed Instructions for the Performance of the Dissolved Oxygen and Biochemical Oxygen Demand Tests," *Supplement* No. **90** to *Public Health Reports* (1931).

[4] Committee Report: "Recommended Procedures for Biochemical Oxygen Demand Determinations," THIS JOURNAL, **4**, 738–54 (1932).

[5] E. J. Theriault, "The Determination of Dissolved Oxygen by the Winkler Method," *Public Health Bulletin* **151** (1925).

[6] E. J. Theriault and P. D. McNamee, "Dissolved Oxygen in Presence of Organic Matter, Hypochlorites and Sulphite Wastes," *Ind. & Eng. Chem., Anal. Ed.*, **4**, 59–64 (Jan. 15, 1932).

[7] E. B. Phelps, "Stream Pollution from the Operator's Point of View," THIS JOURNAL, **2**, 555 (Oct., 1930).

[8] E. J. Theriault and P. D. McNamee, "Sludge Aeration Experiments. I. Rate of Disappearance of Oxygen in Sludge," *Ind. Eng. Chem.*, **22**, 1330 (Dec., 1930).

[9] H. H. Wagenhals, E. J. Theriault and H. B. Hommon, "Sewage Treatment in the United States," *Public Health Bulletin* **132** (1924).

[10] H. W. Streeter and E. B. Phelps, "A Study of the Pollution and Natural Purification of the Ohio River. III. Factors Concerned in the Phenomena of Oxidation and Reaeration," *Public Health Bulletin* **146** (1925).

[11] "Symposium on Stream Pollution." Reprint No. 1063 from *Public Health Reports* (1926).

Discussion

Mr. F. E. Daniels, State Dept. of Health, Harrisburg: Mr. Hoskins has told us a great deal about B. O. D. and the enormous amount of work done on the subject from the time it was first observed in 1870 to the present day. Notwithstanding all this, if he has not already seen the article, he will be pleased to know that a publication by two authors, appearing a few months ago, comes to the conclusion that the B. O. D. is the result of bacterial activity, and that if the sample be sterilized by heat or toxic substances and kept in a sterile condition no B. O. D. will occur.

Work done in Mr. Hoskins' laboratory in Cincinnati indicates that before a B. O. D. in sufficient amount to be measured can be obtained, there must be present living and multiplying bacteria of at least 100,000 per cc.

Mr. Hoskins also pointed out the necessity for the presence of plankton organisms to act as scavingers to feed on the bacteria so as to stimulate their growth and multiplication. He also mentioned another important point, the proper neutralization of toxic substances.

In other words, our sample *must* be in a condition favorable for the growth of bacteria and plankton.

Since we have no tests with which we can check our B. O. D., we have been wondering if we could not use bacterial determinations to show whether or not the sample, as incubated, is in a condition favorable to bacterial growth and hence infer with a reasonable degree of surety that the B. O. D. obtained is correct. In other words, if we are sure that oxidizable organic matter is present and we do not get a reasonable bacterial growth, is it not reasonable to assume that the low B. O. D. obtained is due to the presence of some toxic substances instead of the absence of bacterial food?

Then again, in the absence of some accurate measure of the bacterial food, how are we to determine when the toxic substances are properly neutralized?

A case in point: In our Ohio River work we got some seemingly very low B. O. D. results. Were these figures low because the bacterial food from the entering sewage had been removed by precipitation or stabilized in some other way, or were there present toxic substances which inhibited or prevented proper bacterial activity? I leave that for some one to answer.

This is an important matter connected with the study of streams receiving coal mine drainage. Who knows how to remove or neutralize all the toxic substances in streams contaminated with coal mine drainage or unknown industrial wastes without affecting the oxidizable organic matters to such an extent that the B. O. D. results are unreliable?

When the B. O. D. results are low it is usually recommended to dilute the sample to a point where an appreciable B. O. D. will be obtained. But who knows where to stop? Will the bacterial food become exhausted before the toxic substances, mercurial salts or formaldehyde, for example, be sufficiently diluted to allow bacterial and plankton growths?

We attempted to do some work on these questions at Harrisburg this year, when lack of funds suddenly put an end to our research.

Mr. H. M. Freeburn, Philadelphia: As I understand it, lime, and iron as well, will interfere with B. O. D. tests. If this is the case, how much can you add to sewage without interfering with the test?

A Member: I think if you had an excess of iron, the best thing to do is to use a modification of the dissolved oxygen test in order to prevent interference.

Mr. Freeburn: What do you call an excess?

Mr. Hoskins: Over 0.1 p. p. m. would interfere. Mr. Daniels brought up the point of checking the bacterial content. The principal difficulty is that bacteriologists do not count the bacteria very accurately. The total bacterial count is rather difficult to make, except in com-

paratively rough figures. Of course our counting is mostly done by counting growths on plates and we know that a very small number occur on plates.

Mr. Freeburn: Are there any other tests you can run with the B. O. D. test to check it to see if you are getting the proper results?

Mr. Hoskins: I think the best way to check up is to run another sample. I do not know that there is any similar determination that will exactly check your B. O. D. test.

Mr. C. C. Agar, New York State Dept. of Health, Albany: Mr. Hoskins spoke about the value of the oxygen demand test in controlling or determining the B. O. D. of activated sludge. I wonder if he could explain the procedure or technique necessary.

Mr. Hoskins: Of course, that procedure is primarily a circulation of air through a sample of sludge to determine the drop in the oxygen content after a certain time. That has been done on samples but the results are reasonably accurate and check quite well.

Heat Transmission in Sludge*

BY E. R. QUEER

Engineering Experiment Station, Pa. State College, State College, Pa.

A survey of the literature reveals a distinct trend toward the use of heating coils to accelerate the rate of digestion of sewage sludge. However, there appears to be little information available regarding the rate of heat transfer between the heating coils and the sludge. At the suggestion of Professor Walker, head of the Department of Civil Engineering of the Pennsylvania State College, tests were undertaken to provide these data which are essential when designing systems of this kind.

Heat, in flowing from a heating medium within a coil to a fluid surrounding the coil, passes through three resistances. First, that of the inside pipe surface $\left(\frac{1}{h_i}\right)$, second, that of the pipe walls and third, the outside pipe surface resistance $\left(\frac{1}{h_o}\right)$. These may be combined into an over-all resistance, or the reciprocal of this value would be the over-all heat transfer coefficient from the heating medium to the fluid being heated. In this research the outside surface coefficient (h_o) from the pipe to the sludge has been considered in detail.

The surface heat transfer coefficient (h_o) from a heating surface to a fluid is affected by the characteristic linear dimension (L) of the body, such as diameter of the pipe or height of a heating surface; thermal conductivity (k) of the fluid medium; density (ρ) of the fluid; coefficient of thermal expansion (β) of the fluid; absolute viscosity (μ) of the fluid; temperature difference (θ) between the heating surface and fluid; specific heat (C_p) of the fluid; and the acceleration of gravity (g). By dimensional analysis these variables have been correlated in the following equation[1, 2]

$$\frac{h_o L}{k} = \text{function of } \left(\frac{\rho^2 g \beta C_p L^3 \theta}{\mu k}\right) \qquad (1)$$

King[2] has worked out a series of curves for air, water, alcohol and transformer oil, making possible a solution of the coefficients by this correlation. If sufficient data are available upon these physical characteristics of a fluid, the coefficient (h_o) can be calculated, using the correlation values of both Fishenden and Saunders, and King.

Lack of the physical data for the sludge used in these tests made it necessary to measure the coefficient directly by experimental procedure.

* *Presented before the Seventh Annual Conference of the Pennsylvania Sewage Works Association, State College, Pa., September 6, 1933.*

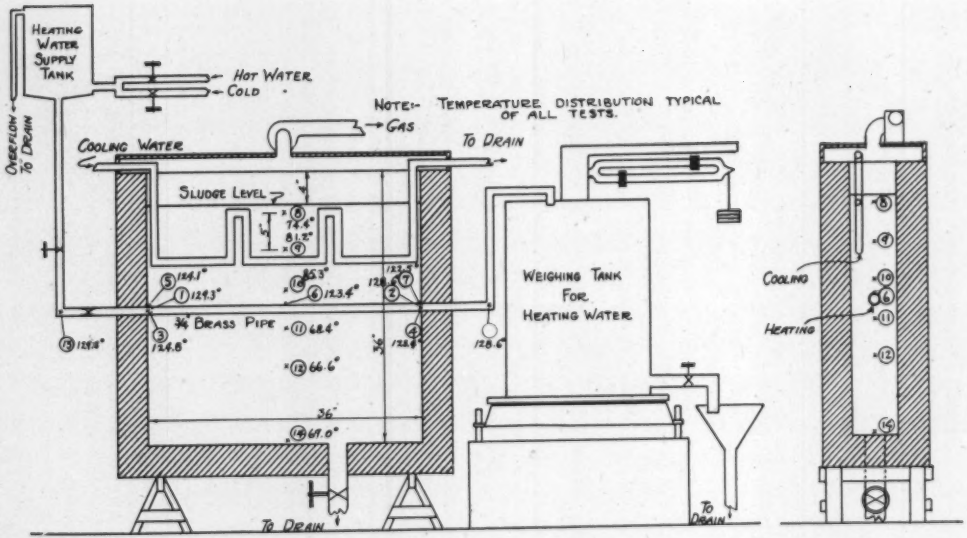
HEATING WATER SUPPLY TANK
OVERFLOW TO DRAIN
HOT WATER
COLD
NOTE:- TEMPERATURE DISTRIBUTION TYPICAL OF ALL TESTS.
GAS
COOLING WATER
TO DRAIN
SLUDGE LEVEL
74.4°
81.2°
124.1°
129.3°
85.3°
123.4°
123.5°
128.6°
WEIGHING TANK FOR HEATING WATER
¾" BRASS PIPE
68.4°
124.8°
66.6°
128.6°
36"
61.0°
TO DRAIN
TO DRAIN
COOLING
HEATING

FIG. 1.

The apparatus shown in Figure 1 was the design finally used for this purpose. The apparatus was calibrated with water in the sludge tank and using water as the heating medium. The physical properties of water are well known; and the values obtained by the correlation outlined and those of the test showed good agreement.

For the inside pipe coefficient the equation of Lawrence and Sherwood[3] was used in the calibration of the apparatus to calculate the heat transfer coefficient through this surface:

$$h_i = \frac{1.8\,(t + 100)\,V^{0.8}}{L^{0.2}} \text{ B. t. u./hr./sq. ft./° F.} \qquad (2)$$

where h_i = inside surface coefficient
V = velocity of flow of water in pipe in feet per sec.
t = average water temperature
The other symbols correspond to those of equation (1)

Apparatus

In the original apparatus the heating coil was an iron pipe. Although expert skill was used in installing the thermocouples, considerable difficulty was experienced in obtaining a reliable calibration of the apparatus. After several days of service, corrosion and scale appeared on both inner and outer surfaces of the pipe. These factors materially reduce heat transfer coefficients.[4] The iron pipe, after a few tests, was discarded for a brass pipe which would withstand corrosion for a much longer time. Although the conductivity of brass is greater than that of iron, the effect of the type of metal used in the heating coil is negligible. The pipe resistance is considerably smaller than that of either the inner or outer surface.

The measurements of a true pipe surface temperature, or, in fact, that of any surface surrounded by a fluid and transferring heat from one to the other, is extremely difficult. In these experiments the thermocouples were applied by cutting a shallow tranverse groove $^3/_4$ in. long in the pipe surface so that the lead wires were made flush with the surface and carried out in an equi-temperature plane. The tip of a No. 30 enameled constantan wire was soldered into one end of the groove, and the remainder of the wire placed in the groove was insulated electrically from the pipe by wrapping with a fine silk thread. The thread covered wire was cemented into the groove and baked at a temperature of 300° F., producing a smooth, hard surface very similar to that of the pipe. One copper wire to complete the thermocouple circuit served as a common line for all the thermocouples and was attached to the brass pipe outside the sludge tank in a manner similar to the constantan. The close agreement between the test and calculated results upon water showed that this method of measuring surface temperatures was satisfactory.

The final arrangement of the apparatus used is that shown in Figure 1.

The numbers in the circles show the thermocouple locations and correspond to the order of taking readings during a test. The temperature distribution indicated is typical of that obtained for all the tests. The heating water was mixed in an overhead tank that was provided with an overflow to give a constant head supply. The heating water was diverted around the sludge tank until it had reached a constant temperature and flow through adjusting the hot and cold water valves. During a test the heating water was carefully weighed after passing through the sludge tank. At the end of a test, cooling water was run through both the cooling coil and the heating coil overnight, so that the sludge was sufficiently cooled for the next day's work. The cooling coil stood idle while a test was in progress.

At the start of a test the sludge temperature was about 55° F. The final temperature depended upon the length of test and the temperature of the heating water. The maximum did not exceed 100° F. at any time.

Heating the sludge speeded up the process of digestion and a considerable quantity of objectionable gas was discharged into the room. A sealed hood was placed over the tank and these gases were forced out of doors.

The average duration of the tests was about seven hours and during this time complete sets of thermocouple readings were taken every twenty minutes. Water weighings were made every ten minutes.

Discussion

The apparatus was calibrated with water in the sludge tank. For comparison of results a sample calculation is made in Table I.

TABLE I

Av. heating water temperature = 140.25° F.
Av. inside pipe surface temperature = 119.4° F.
(Av. of 3 and 4, Figure 1)
Av. outside pipe surface temperature = 118.4° F.
Av. water temperature in sludge tank = 74.4° F.
Rate of flow of water being heated = 1.62 lb. per min.
Av. inlet tank water temperature = 53.0° F.
Av. outlet tank water temperature = 96.4° F.
Temperature rise of heating water in passing through water tank = 96.4 − 53.0 = 43.4° F.
Heat input to tank water = $1.62 \times 43.4 \times 60 = 4220$ B. t. u./hr.
Internal heating pipe area = 0.647 sq. ft.
External heating pipe area = 0.824 sq. ft.

$$\text{Heat flow through internal pipe surface} = \frac{4220}{0.647} = 6510 \text{ B. t. u./sq. ft./hr.}$$

$$\text{Heat flow through external pipe surface} = \frac{4220}{0.824} = 5120 \text{ B. t. u./sq. ft./hr.}$$

$$h_i = \frac{6510}{140.25 - 119.4} = 311 \text{ B. t. u./sq. ft./hr./deg. F.}$$

$$h_o = \frac{5120}{118.4 - 74.4} = 116.0 \text{ B. t. u./sq. ft./hr./deg. F.}$$

Calculated Values

$$h_i = \frac{1.8\,(140.25 + 100)\,\frac{0.8}{0.6001}}{\frac{0.2}{0.822}} = 300 \text{ B. t. u./sq. ft./hr.}$$

h_o by the correlation solution* = 117.2 B. t. u./sq. ft./hr.

This agreement was considered sufficiently close to warrant proceeding with the sludge experiments.

The tank was charged (Figure 2) with well seeded sludge and testing begun. After two days it was found the solids were settling and the heating coil became surrounded by supernatant liquor. The

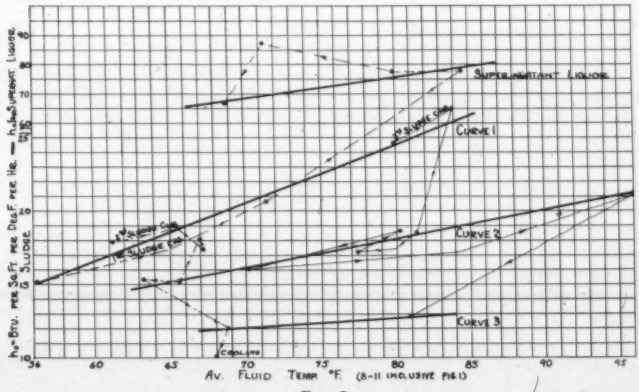

FIG. 2

progression of the tests are shown on Figure 2 by the broken line marked (1st sludge chg.) As the testing proceeded the coefficient increased to that indicated for supernatant liquor. Two weeks later the accumulated liquor was removed from the top of the tank and a second charge (2nd sludge chg.) was added. The dash-dot line shows that the coefficient decreased as the tests progressed, indicating the solids were settling around the heating coil. The supernatant liquor and some sludge were again replaced by a third charge of fresh sludge (3rd sludge chg.—solid line on Figure 2) and the tests were continued at a higher temperature. The coefficients represented by Curve 1 of Figure 2 and in Table II should be used in the region of least concentration of solids

* See references 1 and 2.

TABLE II

Date	Heat Input B. t. u./Sq. Ft./Hr.	Flow Heat. H_2O. Lb./Min.	t Av. ° F. Heat. H_2O	t Av. ° F. Inside Pipe Surface	t Av. ° F. Outside Pipe Surface	t ° F. Av. of Sludge	θ Pipe-Sludge	k_θ-B. t. u./Sq. Ft./Hr. ° F θ	
12–12–32	693	15.87	110.6	103.1	102.0	56.3	45.7	15.2	
12–13–32	762	13.06	115.1	109.5	108.2	71.5	36.7	20.7	
12–15–32	1978	12.07	114.3	107.6	105.2	79.7	25.5	77.5	
12–15–32	1630	11.50	114.0	107.9	105.7	84.7	21.0	77.5	Supernatant Liquor
12–16–32	3120	10.73	119.2	110.3	107.0	71.2	35.8	87.1	
12–21–32	2335	13.04	112.8	101.5	103.7	64.3	39.4	66.8	
12–24–32	749	12.78	107.4	103.9	102.8	61.2	41.6	18.0	
12–27–32	910	13.40	120.3	115.0	113.9	65.5	48.4	18.8	
12–28–32	588	11.24	105.7	102.0	101.0	67.2	33.8	17.4	
12–29–32	680	12.49	109.5	105.3	104.5	67.0	37.5	18.2	
12–31–32	989	13.51	140.0	131.8	130.5	65.6	64.9	15.3	
1– 2–33	985	13.44	134.8	128.5	127.2	63.3	63.9	15.4	
1– 3–33	653	13.73	130.2	124.1	123.0	68.8	54.2	12.1	
1– 5–33	−216	8.19	43.4	46.4	46.8	68.0	−21.2	10.2	
1–19–33	845	14.31	119.3	115.3	114.3	79.4	34.9	24.2	
1–20–33	1362	14.47	142.0	135.8	134.3	83.8	50.5	27.0	
1–21–33	796	14.36	128.9	124.1	123.3	77.4	45.9	17.4	
1–21–33	782	14.38	128.5	123.9	122.9	81.4	41.5	18.9	
1–23–33	681	14.41	117.7	113.8	112.5	70.2	42.3	16.1	
1–23–33	600	14.24	117.0	113.2	112.3	80.2	32.1	18.7	
2– 7–33	386	11.91	118.6	115.2	114.6	96.3	18.3	21.1	
2– 8–33	526	11.79	126.9	122.6	121.8	80.9	40.9	12.9	

or that of active digestion. Those of Curve 2 in the region of medium concentration of solids, and those of Curve 3 in the region of highest concentration that is to be heated. As the sludge became more densely settled around the heating coil, thus increasing its viscosity, the coefficient progressively decreased. Although the coefficient in the supernatant liquor region is considerably higher than any other place in the tank, it is not desirable to do any heating in this region. The low viscosity of the liquor increases the tank heat losses.

The coefficient obtained indicates that the viscosity of the sludge mixture is quite high. The average temperatures for the first test of Jan. 21, 1933, are shown on Figure 1. On account of the high viscosity the temperature dropped rapidly from the heating coil up through the sludge (points 10, 9, 8). From the temperature distribution observations it was concluded a 15- to 24-inch spacing of the heating coils both horizontally and vertically would give satisfactory heating. Additional experiments were made to determine the viscosity. By the falling sphere method it was found to be about 1000 times that of water at the same temperature. A compensating factor that would diminish the effect of such a high viscosity upon the coefficient is the turbulence caused by the gases evolved from digestion.

When the tests were completed the apparatus was dismantled and the

heating coil examined. No incrustation or corrosion had formed on the outer pipe surface, the metal being relatively clean. However, the inner pipe walls had a slight hard-water deposit upon the surface. As a result of this scale the calculated inner coefficient from Equation (2) does not agree with the test value.[4]

Summary

The results of these experiments have indicated some facts which it is believed by the author can be successfully applied to the design of a sludge tank heating system. If the tank is well insulated, the heating coil distribution might be made upon the basis of the test results of Rudolfs and Miles.[5] They have found that the region of active digestion apparently is a function of the total height of the sludge in a tank and is located at about 50 to 60 per cent of the sludge height up from the bottom of the tank. A bank of heating coils using the coefficient of Curve 1 of Figure 2 should be distributed in this region. It would be unwise to place heating coils in a region higher than 60 per cent of the sludge height because they would be ineffective in supplying heat to aid digestion. Furthermore, the viscosity of the supernatant liquor is quite low and the tank heat losses would be increased. The second bank of tubes using the coefficient of Curve II should be placed in the 35 to 50 per cent height region, and the third bank, using Curve III, in the 25 to 35 per cent height region. On account of the high viscosity and poor convectional heat transfer in sludge, the heating coils should be spaced about 15 to 24 inches upon centers both horizontally and vertically.

Sludge heating in the region below 25 per cent would be useless because of the inertness of this material. Furthermore, the digested sludge on the bottom of the tank serves to limit the heat loss through that part of the tank.

Conclusions

1. Sludge has a relatively low heat transfer coefficient from a heating coil on account of its high viscosity.
2. Heating is most advantageous in the region of active digestion, because that is the point where the heat is most useful and the sludge heat transfer coefficient is the highest.
3. With the heating water temperature around 130° to 140° F. the heating coils will remain quite free from incrustation.
4. Using water as the heating medium, the heating requirements can be varied to meet the climatic conditions by a variable speed circulating pump.
5. Heating coils should be spaced 15 to 24 inches upon centers in the heating regions.

References

[1] M. Fishenden and O. A. Saunders, "The Calculation of Heat Transmission," p. 91. His Majesty's Stationery Office, London, England.

[2] W. J. King, "Heat Transmission," *Mechanical Eng.*, p. 349 (May, 1932).

[3] O. E. Lawrence and T. K. Sherwood, *Ind. Eng. Chem.*, **23** 301 (March, 1931).

[4] McAdams, "Heat Transmission," pp. 301–302. McGraw-Hill Pub. Co., 1933.

[5] Willem Rudolfs and H. J. Miles, "Heat Losses from Sludge Digestion Tanks," *Sewage Works Journal*, **5**, 17 (January, 1933).

Discussion

Mr. C. C. Agar, New York State Dept. of Health, Albany: Has any one had any experiences with the use of conventional type hot water radiators suspended in the digestion tank instead of the usual coils for heating? We have in New York State two such installations, one of which apparently operates satisfactorily. This installation is at a small plant and consists of a coal fired boiler with hot water circulation by thermal convection through rather large radiators placed near the top of the tank. The second installation is also at a small plant and is equipped with both a coal-fired and gas-fired boiler with a similar method of circulation and location of the radiators. This latter installation has not been satisfactory.

Mr. E. B. Besselievre, The Dorr Co., New York City: The transfer of heat units in a sludge digester, from the coils of pipe used to carry the heating water, is a subject of much importance. The principal factors to be considered are the type of pipe used, the placement of the pipes on the walls of the tank, the temperature of the ingoing hot water and its relation to reduction of heat radiation from the coils due to insulation by caking.

In general, in the smaller digesters it has been the custom to use galvanized iron pipe and this seems to have been satisfactory. In one of the larger plants now under way the pipe used will be cast iron flanged pipe, in regular lengths, with fillers at the joints to make up the angle of about 22 degrees.

Placement of pipes is a matter of argument but most authorities seem to agree that they should be near the vertical center of the tank. A recent perusal of the records of a number of plants shows that the first, or lowest, coil is placed at an average of 6 feet above the bottom of the tank. The question of the number of coils is more a matter of the amount of radiation surface required than anything else. The average number of coils in the tanks above referred to is 4 coils per tank, with a maximum of 6 and a minimum of 2. In general, not less than $1^1/_2$-inch pipe is considered desirable for coils.

A recent survey made by the writer's company on a total of 11 digestion tanks equipped with coils showed the answer to the question in the questionnaire, "Is there any evidence of caking on the coils?" to be, "No."

Some of these units had been in operation four years. Very few of them had ever been drained down for the purpose of coil inspection, and the negative answer to the question in every case is believed to be an assumption based on the fact that the relationship between the ingoing hot water and digestion tank temperatures had not changed, showing that apparently the same amount of heat was being transmitted to the sludge from the pipes.

The question of caking on coils is undoubtedly dependent upon the temperature of the ingoing water, and the above mentioned survey confirmed the fact that when temperatures of ingoing water were kept at not over 140° F., caking did not occur to a noticeable degree. The average ingoing temperature in the surveyed units was 133° and the outcoming, cooler water was 119°, showing an average drop of 14 degrees. A number of these units were in Northern Wisconsin, where very cold winters are experienced.

Mr. L. E. Burnside, Sharon: What form of insulation is used?

Mr. Agar: The only insulation at many New York state plants is earth embankment. One new plant just completed has a layer of hollow tile around the tank above the ground elevation with an air space between the tank and the tile layer. It is interesting to note that this plant is also provided with a drain around the bottom of the insulating collar to remove any water which may collect in the insulating layer. Provisions are being made also for insulation of exposed tanks at two other plants by construction of tile collars around the exposed portions.

Mr. I. S. Walker, Philadelphia: In regard to the material of pipes, we made a few inquiries lately and found that galvanized iron pipes are in general use. In the design I am now working out I have used black puddled iron pipe without any coating in order to avoid any danger of electrolytic corrosion resulting from the acids in the digestion sludge. With galvanized steel or iron pipe there would be some danger of such corrosion.

Mr. J. F. Laboon, Pittsburgh: In a recent trip to northern New York state I observed the digestion tanks were insulated with two inches of cork. I see no reason why this cannot be applied to tanks above ground. In roofing you will apply cork or some sort of material and top that with your five-ply roof. This cork insulation could be wrapped around a tank by some similar process.

Author's Closure: Hot water radiators would not offer a very economical method for heating sludge, because of localized heating and the poor convectional transfer of heat in sludge. The necessity of good heating coil distribution in sludge tanks has been discussed in the paper.

It is obvious that good drainage around insulated sludge tanks is necessary. Water is an excellent conductor of heat and as soon as the insula-

tion becomes saturated with it the insulating value is destroyed. Cinders used in 24- to 30-inch thickness offer considerable resistance to heat-flow if they are well drained.

The material used in heating coils makes very little difference as far as the external surface heat transfer coefficient is concerned. The resistance offered to heat-flow by the sludge bounding the pipe is many times that of the metallic pipe. Thus the importance of the thermal conductivity of the heating coil upon the external heat transfer coefficient is negligible.

[EDITORS NOTE: Further discussion will follow in the January issue.]

Laboratory Studies of the Activated Sludge Process by Mechanical Apparatus*

BY R. A. VOELKER

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Experiments have been carried on in the laboratory to determine the operating characteristics of the activated sludge process, using one form of mechanical apparatus. An effort was made to establish the value of certain control indices.

Apparatus.—The experiments were carried on in a model activated sludge tank fitted with a type of mechanical apparatus used for aeration. The tank was rectangular in plan, with a series of revolving paddles placed along one side in a longitudinal direction. Revolving paddles, placed over a longitudinal baffle wall, caused the sewage to flow upward along the wall of the tank, and then forced it to flow across the tank in a thin surface layer to the opposite wall, where it was deflected downward to the bottom and then back to the baffle. Oxygen was supplied to the activated sludge mixture both by absorption at the surface and by the spray thrown up from the paddles.

The tank used in the experiments was 18 in. long by 12 in. wide by $5^{3}/_{4}$ in. deep, and was a replica of plant-scale installations. The paddles consisting of four metal arms, each with three narrow longitudinal strips, were 3 in. in diameter; they were immersed in the sewage $^{5}/_{8}$ in. The speed of the paddles was 120 r. p. m. during the first part of the experiments; following a change in the drive gears to replace worn parts, the speed was 136 r. p. m.

The velocity of the sewage across the tank was found to be greater immediately below the surface than at the surface; this fact has also been noted in plant installations. The velocity of this layer was estimated at between 2.0 and 2.5 ft. per second. The circulation produced by the paddle arrangement was very efficient, as evidenced by the fact that a solids concentration of 5000 p. p. m. was maintained satisfactorily by the apparatus at one time.

Procedure.—The experiments were controlled on the basis of suspended solids concentration in the aeration tank. The concentration was varied throughout a range of 300 p. p. m. to 5000 p. p. m. The other operating details were kept as constant as possible. The period of aeration was kept at six hours.

The fill-and-draw, or batch, process was used. The procedure followed was the daily addition of half the capacity of the tank of raw or of screened

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sewage, as influent, to an equal amount of activated sludge settled from the previous day's run. The influent sewage was taken from three sources all principally domestic, and varied in strength between 75 p. p. m. and 500 p. p. m. suspended solids, and between 115 p. p. m. and 700 p. p. m. B. O. D. Return activated sludge from a plant using compressed air was used to start the experiment.

The tests lasted ninety days and during this time fifty-two sets of readings were obtained. These tests were divided into two groups. In both groups the period of aeration was six hours. In the first group, composing thirty-seven sets, the previous period of inactivity of the activated sludge was between sixteen and nineteen hours (*i. e.*, overnight), and the amount of influent added was 9.6 to 9.75 liters. In the second group, composing fifteen sets, the amount of influent, although generally within the range noted above, was as much as 10.7 liters in a few cases; the period of previous inactivity was sometimes as high as forty-two hours to include all runs made immediately following the week-end. A comparison of the results obtained showed no significant difference.

At the beginning of the experiment, the suspended solids concentration in the tank was 600 p. p. m. This was built up continuously to about 5000 p. p. m. During this time no sludge was wasted, only effluent after settling being drawn off from the tank. After 5000 p. p. m. concentration was reached, a portion of the activated sludge mixture was wasted every day so that the solids concentration was gradually lowered to 300 p. p. m. at the conclusion of the experiments.

The analyses made for each run were suspended solids and ash for influent, tank mixture and effluent. The per cent settling of the sludge mixture in thirty minutes was obtained. The 5-day B. O. D. of the influent and the effluent were measured, and the turbidity of the effluent. On the last fifteen runs, ammonia was determined in the influent and effluent, and nitrate in the effluent.

The sample for suspended solids in the tank was taken after vigorous stirring of the mixture in the tank. The sample was then dipped out by a tube of exactly 50 cc. capacity. In spite of the care exercised, the sampling error was high, as was demonstrated by a comparison of the results. For the remaining analyses, a one-liter sample, taken from the thoroughly mixed tank content, was poured into a liter graduate, and settled for thirty minutes, and the per cent settling noted. The supernatant liquid, considered as the effluent of the process, was siphoned off from the graduated cylinder after the thirty-minute period.

Discussion.—Certain criticisms may be advanced regarding the procedure used. In the first place, although the tank was designed with the idea of keeping the proportions comparable to those of plant-scale installations, it is difficult to do this from a practical standpoint. In

addition, in any models of this sort, it is desirable that the hydraulic characteristics of the installation be directly comparable to those existing in large-sized tanks. This situation probably did not hold in the model used. For these reasons it is probably true that the definite figures established by these experiments may not be found in plant-scale operation, but, at the least, all general trends should be applicable.

Second, it is felt by some investigators that results obtained by the batch process are not applicable to plants which operate with continuous flow. There are no data here which would clear up this point but, as mentioned before, the general trends shown by this experiment should always hold.

The point has also been made that, since the suspended solids concentration in the aeration tank was being changed continuously, the efficiency of the process produced by one definite concentration might not be shown by the analyses for that particular run, but would be modified by the hold-over effect of the runs preceding it. In this connection, it is noted that, since the complete series of experiments covered both a range where the concentration was increasing as well as a range of similar extent where it was decreasing, the lag which possibly exists in the first half of the experiments should be balanced by an equal and opposite lag in the second half. As a matter of fact, where a comparison is possible, the analytical results in both parts of the experiment showed no pronounced difference.

Finally, the continuously changing character of the activated sludge should be pointed out. This change may be directly reflected in the efficiency of the process, as measured by the ordinary indices, or it may be an entirely distinct function.

Suspended Solids Concentration

Results.—In attempting to correlate the data obtained by the experiments, a study was made of the effect of the suspended solids concentration in the aeration tank on the efficiency of the process. In this connection, graphs were plotted of solids concentration in the tank *versus* the suspended solids of the effluent; secondly, of solids concentration *versus* the B. O. D. of the effluent.

The mean lines plotted from the points show that clarification—as measured by suspended solids—is poor at the lower limit of 300 p. p. m. solids concentration, but improves rapidly to a critical and sharply defined point at about 1200 p. p. m. concentration. Above this point and through to the upper limit of 4700 p. p. m. concentration, there is a steady, but relatively slow, improvement in clarification. The definite figures at the significant points of the curve are as follows: concentration 300 p. p. m., effluent suspended solids 126 p. p. m.; 1200 p. p. m., 46 p. p. m.; and 4700 p. p. m., 24 p. p. m. (Figure 1).

Mean lines were plotted similarly for the B. O. D. of the effluent, B. O. D. being here assumed as a direct measure of stabilization. These mean lines exhibited the same general characteristics noted in the curve for suspended solids, showing a fairly rapid increase in efficiency up to a critical point, followed by an improvement of minor extent. However, it is significant that the point between the two slopes for the B. O. D. curve came at about 1900 p. p. m. solids concentration. Comparing further the curves for suspended solids and B. O. D., the slope of the mean lines for B. O. D. is not so steep, and the critical point is not so sharp nor so clearly defined. Definite figures for B. O. D. at the different solids concentrations are as

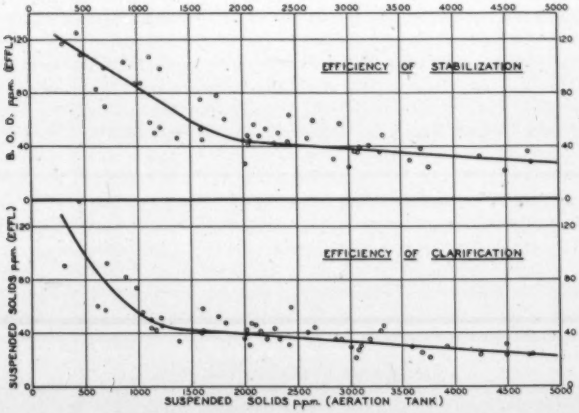
EFFICIENCY OF STABILIZATION
B. O. D. ppm. (EFFL.)
EFFICIENCY OF CLARIFICATION
SUSPENDED SOLIDS ppm. (EFFL.)
SUSPENDED SOLIDS ppm. (AERATION TANK)

FIG. 1.—Relation Between Solids Concentration in Aeration Tank and Efficiency of Process.

follows: concentration 300 p. p. m., effluent B. O. D. 120 p. p. m.; 1900 p. p. m., 46 p. p. m.; and 4700 p. p. m., 29 p. p. m. (Figure 1).

In explanation of the statement that B. O. D. may be taken as a measure of stabilization, it has been established before that a direct correlation exists between the suspended solids of a sewage or plant effluent and its B. O. D. Approximately 70 to 75 per cent of the B. O. D. may be attributed to the suspended solids. To indicate the correlation for this particular experiment, a graph was made up in which the suspended solids content of the effluent in the individual runs was plotted against the respective B. O. D. figures (Figure 2).

The mean straight line of the points plotted, as calculated mathe-

matically, shows that as the suspended solids increase the B. O. D. values increase at a greater rate. The B. O. D. of the effluent averages 1.3 times the suspended solids.

As a matter of general interest, a similar plotting and calculation was made for the influent sewage. Here the B. O. D. values averaged 1.5 times the suspended solids.

As noted before, the strength of the influent sewage varied over a wide range. An investigation was made as to the effect of strength of influent sewage on the character of the effluent. A correlation by graph was made of suspended solids in the influent against those in the effluent. One graph

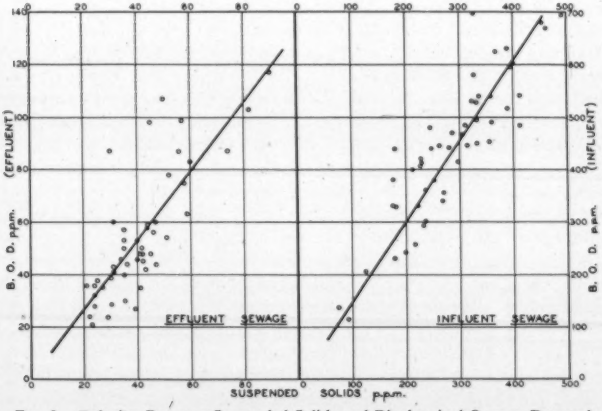

FIG. 2.—Relation Between Suspended Solids and Biochemical Oxygen Demand of Sewage.

was made using the figures obtained at the range of solids concentrations in the activation tank of 300 p. p. m. to 1200 p. p. m. A second graph showed the figures obtained at the higher range of 1200 p. p. m. to 4700 p. p. m. The lack of a sufficient number of points in the first graph made a conclusion difficult, although the trend is evident that, within the range of 300 p. p. m. to 1200 p. p. m. the character of the effluent depends on that of the influent; with higher suspended solids in the influent, there results higher solids in the effluent. On the other hand, the similar plotting for all readings above 1200 p. p. m. concentration provided no mean line, and indicated that the activated floc reduces the suspended solids in the effluent to the same point, regardless of the load.

A second correlation was made using the B. O. D. figures for influent and effluent. The range for the first graph was 300 p. p. m. to 1900 p. p. m. concentration, and the second showed all figures above 1900 p. p. m. The same conclusions resulted as noted for suspended solids.

Conclusions.—In the two sets of curves drawn, showing the concentration of suspended solids in the activation tank *versus* the efficiency of clarification and of stabilization, it is concluded that there is a definite and comparatively narrow range of suspended solids concentration, below which the efficiency of the activated process is materially decreased, and above which the efficiency increases only a relatively small amount. However, this latter improvement in efficiency is continuous up to a very high solids concentration.

It has been noted that in these experiments the critical point for clarification was around 1200 p. p. m., and that for stabilization was approximately 1900 p. p. m. This accords with the theory that the purification effected by the activated sludge process depends on the mass of the active floc. The function of the floc is, first, the mechanical adsorption and mass precipitation of the sewage solids, and, second, the stabilization of these solids by the biological activity of the floc. From this standpoint, it is logical that, up to a certain concentration of activated floc, the mass of active material will not be sufficient to handle the total amount of sewage solids, either by precipitating them or by stabilizing them biologically. As the concentration of the floc is increased, a point will be reached where the mass of active floc material will be just sufficient to handle all of the sewage solids. Above this critical concentration, the total mass of floc is not necessary, and no great improvement in the process should result.

The present experiments have demonstrated also the fact that a higher concentration of floc is necessary for a satisfactory stabilization than is required for clarification alone. That is, the amount of floc which is exactly sufficient to adsorb and precipitate the sewage solids is not sufficient to stabilize them satisfactorily.

Keeping in mind the effect of mass of floc on the total solids handled, it is logical to assume that a weak influent sewage, *i. e.*, one of low solids content, could be handled by a lower floc concentration than would be required by sewage of normal strength. The investigations made of this detail, studying the character of the influent and effluent in the lower and in the higher floc concentrations, tend to indicate that below the critical concentration the character of the effluent depends on that of the influent. Above the critical concentration, the character of the effluent is not affected by the load placed on the process.

The correlation shown by the graph between the suspended solids and the B. O. D. of the effluent is interesting for one feature. It has been noted that the B. O. D. values increased at a greater rate than did the suspended

solids. This may be interpreted as follows. In this particular experiment, poor efficiency of treatment resulted not only in more suspended solids in the effluent, but also in a less complete oxidation of these solids. As better clarification was effected (by the higher solids concentration in the tank), the suspended solids were smaller in quantity and also more completely oxidized.

Sludge Index

Results.—An investigation was made of the value of the sludge index as a measure of the quality of the activated sludge. For this purpose a

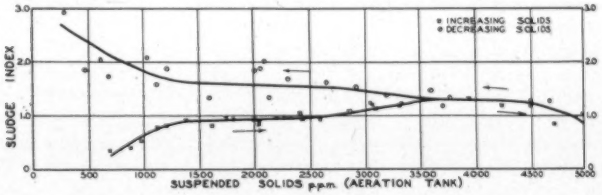

FIG. 3.—Relation Between Solids Concentration in Aeration Tank and Sludge Index.

curve was plotted showing the relation between the suspended solids concentration in the activation tank *versus* the sludge index, Figure 3. Another curve was plotted of sludge index *versus* the suspended solids of the effluent, Figure 4. This latter plotting indicated that within the range

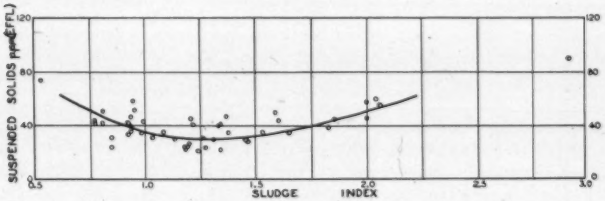

FIG. 4.—Relation Between Sludge Index and Efficiency of Process.

of the points (0.75 to 2.0 sludge index), clarification was poorer at the two extremes, and became better as an index value of 1.25 was approached.

Discussion.—In studying Figure 3, the plotted points must be taken in chronological order. At the beginning of the experiments the activated floc used was put into a poor condition by letting it stand in the laboratory for several days without proper aeration and without the addition of any

fresh material. By this method, sludge was produced which settled poorly at first, with a low value for the sludge index. As the experiments continued, the condition of the sludge became progressively better. Apparently this improvement continued throughout the experiments, as measured by the sludge index. The sludge index rose sharply during the first period of the experiments from 0.35 to 0.80. With the sludge concentration rising from 1200 p. p. m. to 2400 p. p. m. the sludge index remained constant just below 1.0; then it rose above 1.0 and was constant at about 1.25 for the range 3500 p. p. m. to 4500 p. p. m. It is significant that in this latter range the settling characteristics were the same for both ascending and descending solids concentrations. As the concentration was decreased from 3500 p. p. m. downward, the sludge index rose, and remained constant for some time above 1.50. Following this, in the range 1200 p. p. m. to 300 p. p. m., the curve rose rapidly to 3.0. The curves give therefore, a good indication of the condition of the sludge as well as the effect of concentration. The latter half of the experiments gives a more representative condition than does the first half. The curves show clearly the lagging effect of the poorly aerated sludge. It required considerable time and higher solids concentration to obtain results equal to those obtained with well conditioned sludge. The results indicate therefore that re-aeration of sludge may be a very important factor in operation.

Figure 4 may be used to determine the value of the sludge index as a measure of efficiency. From a consideration of the sludge index alone, without regard for any other factors which might influence the curve, it may be concluded that the sludge index might be of value for general comparative work at any single plant, but that it is unwise for universal use to set up any definite figure above which good results are to be expected. In these particular experiments, there is an upper as well as a lower limit outside of which the process is unsatisfactory.

Ash as an Index for Activated Sludge

Results.—An examination was made concerning the value of the ash content of the activated sludge as a measure of its efficiency. The ash content throughout the experiments ranged between 18 and 29 per cent. A graphical correlation was made between the per cent ash in the activated sludge and the B. O. D. of the effluent (Figure 5). These two sets of figures were plotted against the solids concentration in the aeration tank, and composite curves drawn. In effect, these curves indicate chronologically the variations in the ash content as the experiments progressed, with a low solids concentration at first, built up to a maximum, and then lowered.

The curve of the ash content, beginning at a high value of 26 per cent, dropped to a minimum of 18.5 per cent and then rose to 25 per cent

at about 2500 p. p. m. solids concentration. It then remained fairly constant for the entire period of efficient stabilization. When the critical solids concentration of 2000 p. p. m. was approached with lowering of the concentration in the aeration tank, the ash content began to vary considerably, rising to 27 per cent and then dropping rapidly again to a minimum of 20 per cent. It is particularly noted here that, whereas the points for the first portion of the experiment varied only slightly from the mean line, the values of the ash content when the critical concentration was passed toward the end of the experiment showed considerable fluctuation.

Discussion.—The present experiments may not justify any definite

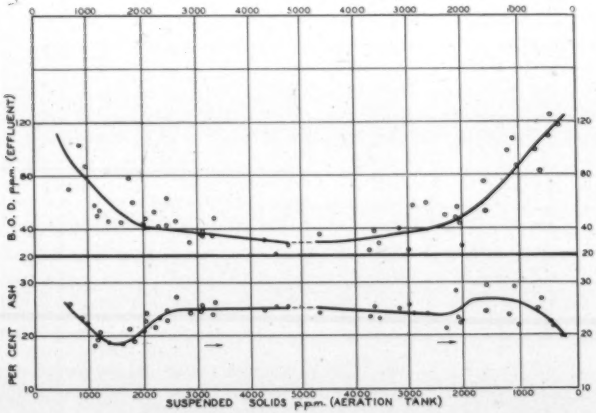

FIG. 5.—Correlation Between Per Cent Ash of Activated Sludge and Efficiency of Process.

conclusions. However, certain tendencies are evident which point to interesting possibilities.

It has been suggested previously by Haseltine at Salinas, Cal., that the existence of a constant ash content in the activated sludge throughout operation indicates that the sludge is being held at an optimum condition of oxidation, and that the proper equilibrium between aeration and load is being maintained. A fluctuation in the ash content is hence interpreted as indicating a disturbance of this balance, with resulting loss in efficiency.

The present experiments bear out this explanation. Throughout the range of efficient operation (2000–5000 p. p. m. solids concentration), the ash remained at 25 per cent and showed very little variation from

this value. On the other hand, throughout the range of inefficient operation (300–2000 p. p. m. solids concentration), the ash content did not remain constant, but changed from day to day. It appears from the present work that, in general, a comparatively high ash content shows optimum conditions, and that a low value results in poor conditions.

The ash figures showed little variation from the mean line when the concentration was being increased from 300 p. p. m. to 2000 p. p. m., whereas great variations resulted during the corresponding decreasing range. In this connection, it may be pointed out that in the latter range activated sludge of a relatively high ash content and of good quality was being wasted daily and being replaced by raw sewage of low ash content. This meant a less stable condition than that obtained in the first portion of the experiment, when no sludge was being wasted. However, it is possible that other quite unrelated factors produced the effect noted.

Summary

Experiments have been carried on to determine certain operating characteristics of the activated-sludge process, using mechanical apparatus. The general conclusions made are probably universally applicable to plant-scale installations, although the definite figures found apply only to these particular experiments.

There is a critical point for the concentration of suspended solids in the aeration tank, below which the efficiency of the process drops rapidly, and above which no marked improvements result. The critical point of suspended solids content for economically efficient clarification is lower than the critical point for stabilization.

The sludge index may be valuable when applied for comparative purposes only at a single plant. Similarly, definite optimum values or ranges of values may be set for one plant, but should not be applied for other installations.

The present experiments are not entirely conclusive in indicating the value of the ash content of the activated sludge as a comprehensive measure of its quality. However, it seems probable that the ash content in a well operating plant should remain constant, with no individual fluctuations, and at a relatively high figure. Fluctuation in the ash content is an indication of a sludge of inferior quality.

The Mechanical Dewatering of Sewage Sludge on Vacuum Filters*

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Recent trends toward increased mechanization of sewage treatment plants have created new interest in the mechanical dewatering of the sludge produced. The idea of mechanically dewatering sewage sludges is not new, for, since the development of sewage treatment on a large scale, the sanitary engineer has continually sought a satisfactory and economical solution to this problem. The advantages of mechanical operation have been fully appreciated, particularly as the operation can be carried on independently of weather conditions and with a minimum of aesthetic offense.

The earliest large scale applications of mechanical devices for this purpose in the United States were at Worcester, Massachusetts, and Providence, Rhode Island, where industrial filter presses of the plate-and-frame type were in use for a number of years. These presses operate under relatively high pressures and in the early days of industrial filtration were used for both clarifying and dewatering. Since the development of the continuous vacuum filter the field of the pressure filter has been narrowed almost exclusively to clarifying operations as the design of the apparatus lends itself most effectively to this function. The pressure filter is at a distinct disadvantage for dewatering, due to the high labor cost for removing the cake and the maintenance of filter cloths.

Early in 1920 the newly formed Milwaukee Sewerage Commission was considering the design of an activated-sludge plant for the City of Milwaukee, Wisconsin, on a scale far beyond any yet attempted, and the problem of sludge disposal became a very important one. Study indicated that the sludge produced by this type of plant had a definite fertilizer value, and that a market could be developed for the waste solids if they could be produced in a suitable form. Sludge drying beds could not be considered for such a project and the Commission investigated numerous mechanical devices for dewatering.

After many failures, the rotary drum type vacuum filter was considered and at the expiration of fifteen months of intensive testing this machine was accepted as the most promising for the work (Figure 1).

Laboratory work carried on at Milwaukee by Copeland and Heisig and at Chicago by Mohlman and Palmer emphasized the necessity of suitable conditioning of the sludge prior to filtration. This work was aug-

* *Presented before the Seventh Annua Conference of the Pennsylvania Sewage Works Association State College Pa., September 7, 1933.*

mented by John Arthur Wilson, who noted the advantages of the application of heat to the sludge with a marked increase in filtering rate as the optimum temperature was reached. Wyman in Pasadena, Fugate in Houston, and others, added to the general knowledge but it was not until the discovery by Palmer of the increased conditioning effect of the trivalent iron salts, such as $FeCl_3$ and $Fe_2(SO_4)_3$, that real strides were made in the dewatering of waste activated sludge on vacuum filters.

With $FeCl_3$ as a conditioning agent it was found that sludges which had been difficult or impossible to dewater with the old conditioners became filtrable and good sludges gave rates comparable to or better than

FIG. 1.—Battery of Twenty-four Vacuum Filters at Milwaukee, Each with a Filter Area of 495 Square Feet

those obtained by Wilson with heated sludges. Due to increased demand a competitive market was created among the manufacturers of this salt and the resultant cost reduction allowed economical consideration of the mechanical dewatering of digested sludges.

During the past three years tests have been conducted at Salem, Columbus and Cleveland, Ohio; Baltimore, Maryland; Los Angeles, California; North Toronto, Canada; and at the West Side Treatment Plant of the Sanitary District of Chicago. Imhoff and separate digested sludges, mixtures of raw solids and waste activated sludge, and various mixtures of activated and Imhoff sludge, have been dewatered. Continued work by Mohlman and Palmer in Chicago and by Heisig in Milwaukee has greatly improved the technique of activated-sludge filtration.

In the January, 1929, issue of SEWAGE WORKS JOURNAL, an editorial states:

"Vacuum filters are quite satisfactory for dewatering activated sludge and may have possibilities for the dewatering of digested sludge, but even though they might be adapted to the handling of the latter, it is questionable whether the cost of operation will ever be low enough to compete with sand beds."

The question expressed in this editorial has been answered in part by

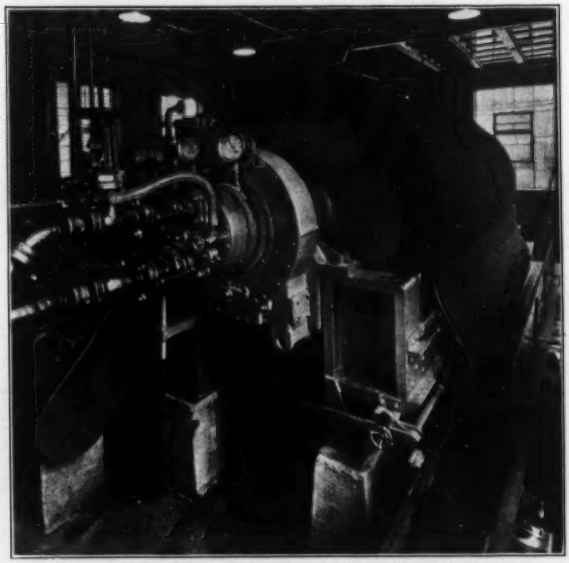

FIG. 2.—Vacuum Filter at Cleveland Westerly Treatment Works. Filter Area 165 Square Feet.

Keefer and Cromwell of Baltimore in an article entitled "The Dewatering of Sludge by Vacuum Filtration" in the November, 1932, issue of the SEWAGE WORKS JOURNAL. This article covers experimental work on two types of vacuum filters carried on over a long period of time. Filter rates and operating costs, including consumption of conditioner, were carefully checked and a cost analysis made on plant scale in comparison with the present sand bed method of dewatering. This analysis shows that at

Baltimore, based on the experimental results, the cost of dewatering digested sludge by this means may be less than on the present sand beds. The authors' conclusions were as follows: "If the results obtained with Baltimore sludge can be duplicated in other places, it would seem fair to assume that vacuum filtration offers an excellent means of drying digested sludge. The process is an economical and practical method of sludge dewatering."

Later, large scale work at the West Side Treatment Plant in Chicago and at the Westerly Plant in Cleveland on Imhoff sludge (Figure 2), substantiated the Baltimore operating results, and smaller scale operation

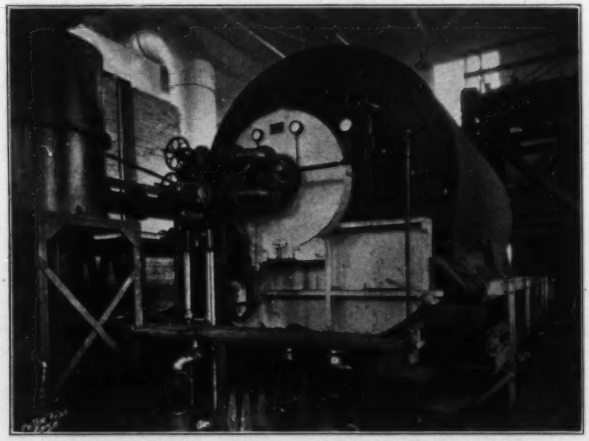

FIG. 3.—Vacuum Filter at the Chicago West Side Treatment Works. Filter Area 570 Square Feet.

at Columbus, Ohio, on the same type of material gave satisfactory and economical results.

Large scale operation at the Chicago West Side Works (Figure 3) on mixtures of raw settled solids and waste activated sludge and on Imhoff and activated sludge with $FeCl_3$ conditioning gave filter rates higher than had been obtained on straight activated sludge, although the consumption of ferric chloride was greater. Goudey at Los Angeles has shown that raw settled solids can be dewatered on a vacuum filter with the addition of lime to the $FeCl_3$ for conditioning (Figure 4). Lime-conditioned, electrochemically treated sludge has been successfully dewatered by Shaner at

Winston-Salem, North Carolina, for a number of years. Chemically precipitated sludges at Dearborn, Michigan, Oklahoma City and at the Guggenheim Brothers experimental plant at the North Side Treatment Plant in Chicago have proved susceptible to satisfactory vacuum filter dewatering. It is regretted that so little has been published on these operations.

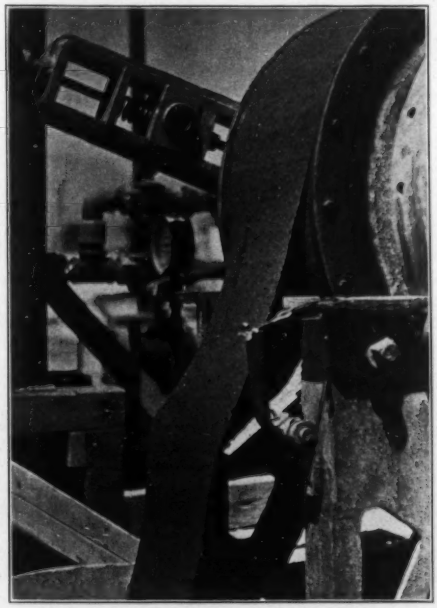

FIG. 4.—Vacuum Filter at Los Angeles Experimental Station. Filter Area 18 Square Feet.

For some unknown reason, the vacuum filter has been considered generally as a mysterious mechanism. This is difficult to understand for it is probably the simplest of all industrial machines. The filter operates on the same principle as the cider press with which every one is familiar, the latter using mechanically applied pressure for forcing the juice out of the pulp and the former using atmospheric pressure for the same purpose. In the cider press the extracted liquid or juice is forced out of the press,

the pulp or cake remaining in the interior. On the vacuum filter the liquid is forced through the filter medium to the interior of the filter while the pulp or cake remains on the outside.

Of the several types of vacuum filters, the rotary drum type is probably the least complex. This machine consists of a sectionalized drum surface covered with a filter medium, such as cloth or metal screen, rotating through a tank or vat. The sludge to be dewatered is placed in the vat. A vacuum pump, connected by means of a special valve to the sections of the drum, evacuates the sections, and atmospheric pressure pushes the liquid through the filter medium and causes the solid matter to remain on the surface as a mat or cake.

In one complete revolution of the drum, the cake is formed while in contact with the sludge in the tank, pressed by atmospheric pressure, dried by the air drawn through the semi-porous cake, and discharged, leaving a clean filter medium to again receive its coat of solids.

The filtrate, or liquid passing through the filter medium into the sections, is carried to the valve of the filter by individual pipes and from the valve to a separator tank where the liquid is drawn off by means of a centrifugal pump and the air exhausted to the atmosphere through a vacuum pump. The filter valve functions in a similar fashion to a three-way cock; shutting off certain sections in order to prevent reduction of vacuum by leakage of air through the bare medium; subjecting other sections to the exhaustion of the air, water or both; and providing for the admission of atmospheric or low pressure air to other sections in order to break down the vacuum and thus release the cake from the surface of the filter medium.

The satisfactory operation of a vacuum filter on any material depends upon a few, but important, conditions. First, the sludge must be filtrable. That is, it must be of such character and in such condition that a ready separation of the suspended solids from the liquid can take place. Second, the sludge must contain sufficient suspended matter for the formation, in a relatively short time, of a cake or mat of sufficient thickness and body to allow easy and complete removal from the filter cloth or medium. Third, the character of the solids must be such as to allow the liquid to be forced through the mat formed on the filter medium by the pressure differential between the atmospheric pressure on the outside of the mat and evacuated section beneath the mat. Fourth, the cake after formation must have sufficient porosity to allow air to pass through it during the drying cycle and thus reduce the surface moisture.

Few mechanical adjustments on the filter can aid in meeting these conditions. A filtrable sludge, or one which is properly treated to insure filtrability, is most important.

Sewage sludge which is colloidal in character requires this essential

preparation, which may be of a chemical or physical nature, or both. Unfortunately, no two sewages produce identical sludges and hence each plant requires, to a certain extent, individual diagnosis and treatment.

It has been our experience, however, that once the diagnosis and treatment of a sludge at a certain plant have been determined upon, reasonably uniform filtration will result.

Definite types of sludges, that is, Imhoff, activated, separate digested, etc., apparently are susceptible to certain classified types of treatment, but experience has not as yet been sufficiently wide and varied to set up empirical formulae which can be used without modification. It is doubtful if such formulae can ever be written, for variations in water and trade wastes, plant design and operation, preclude the production of uniform sludges of the same type.

Practically all sewage sludges can be conditioned for filtration if sufficient conditioner be used but unless the amount of conditioner and its cost is within reasonable economic limits we should not consider the sludge as suitable for vacuum filter dewatering. It is interesting to note that at Baltimore the cost of conditioner was more than half the total cost of dewatering on vacuum filters. It is to be hoped that continued study and wider experience will develop cheaper and more effective conditioners, or cheaper and more efficient means of application of those now available, for, with every decrease in conditioner cost, the vacuum filter becomes a greater economic necessity for sewage solids dewatering.

In Keefer and Cromwell's comparison of the cost of sludge dewatering on vacuum filters and sand beds at Baltimore, it was found that although the conditioner was the major cost in vacuum filter dewatering, the total cost per ton of dry solids handled was less from the filters than from the beds. A recent unbiased survey of sand bed drying costs covering a number of separate sludge digestion plants widely scattered geographically, shows that in plants producing from eight hundred to two thousand tons of bone dry sludge per year, the cost, including fixed charges, averages $4.94 per ton. Similar indicated costs of vacuum filter dewatering of this type of sludge do not exceed $5.00 per ton and in certain instances meet the minimum sand bed figures.

It is certain that if conditioner costs can be reduced slightly or a method of treatment discovered which will reduce the amount required at present, the cost of the vacuum filter will show a marked economic advantage over the best operated open sand drying beds. The same survey showed that on plants of similar size equipped with glass covered beds, the average cost per ton of dry solids removed averaged $8.36, which is considerably higher than vacuum filtration cost under present conditions.

We must consider, however, the method of setting up these costs in order to understand the comparison. Total costs per ton of dry solids

must include, with sand beds as with vacuum filters, fixed charges and operating charges. Using average cost figures for bed construction and vacuum filter installation, with a fixed interest and sinking fund rate, the vacuum filter shows a wide first cost margin in its favor. Under present average conditions, operating costs are somewhat higher with the filters than with the beds. During the past three years, extremely low labor cost has been a substantial aid to the sand bed operator.

Cost comparisons are apt to lead to unexpected developments and in the case of vacuum filters *versus* sand beds, the most interesting has been the apparent possibility of considerably reducing total plant costs if vacuum filters are included in the design. This is not entirely due to the lower first cost of the filter installation. Inability of sand beds to dewater sludge successfully during the winter and wet months makes large sludge storage capacity necessary in careful plant design. Whether this is in the form of excess digester capacity or in separate storage tanks is of little interest, but as an addition to plant cost it is no small item.

Vacuum filters, which operate independently of weather conditions, do not require this excess storage, and the cost saving for this item should be credited on the vacuum filter side of the ledger. It is possible that digester capacity may be reduced well below the present normal operating average if continuous sludge removal is used. Studies are being made of the digestion period required to produce a stable, non-putrescible sludge, and evidence so far indicates that considerably shorter digestion periods will be satisfactory. With the interest now being manifested in complete disposal by means of incineration, the putrescibility of the sludge may be of little importance and digestion need be carried only to the point where the gas production curve falls off rapidly.

If this be proved it is evident that digestion will require some justification. With vacuum filters for sludge dewatering, followed by incineration of the dewatered cake, it would seem that digestion would not only be unnecessary, but an added cost to the plant which could not be justified. Our computations indicate, however, that digestion may be economically desirable, particularly in plants of some size and especially in those fed by combined sewer systems.

In cities where there is no separation between sanitary and storm sewers, statistics show that peak loads of solids to the plant following storm periods, may be as much as five times the normal, and in most plants with separate systems the peak load is three times the dry weather flow. Raw sludge cannot be stored successfully at present although studies being carried on in pre-chlorination may disprove this statement. If storage of raw sludge cannot be effected economically, the same amount of solids must be withdrawn from the plant daily as enters it. On this basis the plant would require filters and incinerators to take care of the maximum

peak loads, which are of relatively short duration. During normal flow conditions this equipment would remain idle, putting an unsatisfactory economic load on the plant fixed charges.

Digesters, however, with little excess capacity over normal dry weather flow can absorb peak solids without difficulty when sludge removal is constant and excess loads on the dewatering equipment can be spread over a considerable period. Again, reduction in volatile matter in the digester reduces the amount of solids to the filters, requiring less filter area and, as the conditioner requirements are in direct proportion to the amount of solids, the cost of this item is reduced. Gas production during the digestion process can be maintained at a maximum by uniform filling and removal of solids and the B. t. u.'s in the excess gas can be used for incineration in a more available form than B. t. u.'s in the filter cake. Our comparative cost sheets indicate that first plant cost, including the digesters, is actually less than with primary sedimentation alone followed by filters and incinerators, and that operating cost is considerably lower due to the reduction in conditioner, power and maintenance costs. The great advantage of the digester, however, is that it provides the necessary balance between peak loads and normal flows.

Activated-sludge plants with sufficient suspended solids in the plant influent to require primary sedimentation, and with a total daily solids warranting incineration, show from our theoretical comparative balances lower first and operating costs if designed with digesters for the primary solids and provision for mixing the raw, waste activated sludge with the digested solids before filtration. We know of no plants which have been operated in this manner and hence are unable to substantiate the theoretical figures but it is hoped that investigation will be stimulated and reliable data secured.

Reports from plants digesting mixed sludges, that is, activated and raw, are not particularly favorable under present methods of operation. It is possible that two-stage digestion will remove most of the present difficulty with the supernatant liquor and it is hoped that as the digestion troubles are overcome, the sludge will be more filtrable. At present, very limited filter tests show an uneconomical conditioner demand.

Most chemically precipitated sludges filter readily, particularly those in which lime is a large percentage of the chemicals added. Care must be taken, however, in making comparisons of filter rates and moisture contents between these sludges and sludges in which little or no lime is added. Comparison should be based solely on sewage solids. The same can be said for all sludges in which large amounts of inert material are added as a filter aid.

It is regretted that it has been necessary to confine this paper entirely to generalities, for specific data are of much greater interest. The very

nature of the subject has, however, required this limitation, for developments at this stage are so rapid and results so variable that the inclusion of specific statements would only be misleading if generally applied. If it has been shown that practically all types of sludges lend themselves to mechanical dewatering, that the vacuum filter dewatering of sewage sludge is comparable in cost to other and, in our opinion, less satisfactory methods, that stimulated interest may further reduce this cost, and that wider study of mechanical dewatering may make important and valuable revisions in sewage plant design, costs and operation, we have achieved our purpose.

Plant Operation

Application of the Sewer Rental Law*

By John H. Fertig

Director, Pennsylvania Legislative Reference Bureau

The concentration of population in restricted areas has created conditions where the health, comfort and convenience of the people require municipalities or public utility companies to furnish various essential services. Not the least important of these services is the collection and disposal of sewage. The common method of collecting sewage and discharging the same by gravity into a stream to be cared for by the dilution method is no longer sufficient, although the practice is still far too common.

Sewerage systems and treatment works have usually been financed by special assessments and bond issues supported by the assessments and tax levies, but the rapid and imperative increase in sewage disposal facilities has lately introduced a new method of financing the annual costs which is now receiving a great deal of attention in many states. Experience is beginning to teach us that which we knew but did not appreciate, that a sewage service is primarily a utility service, the same as light, heat, power and water; and that methods of financing may be applied similar to those used in the case of other utility services, in which the cost is collected from the actual users of the service. In the report of the National Committee on Trade Recovery[1] it is said: "A self-liquidating sewerage system differs from a self-liquidating water works in only one way, the commodity sold. In the case of water works the transaction is for the delivery of clean water. In the case of a sewerage system the transaction is for the disposal of dirty water." While this statement may be somewhat broad it is, to a great extent, sound.

Development and Purpose of Rental Laws

While the keen interest now being displayed in sewer rental laws is of rather recent origin and stimulated by the economic depression, Massachusetts provided for the collection of "just and equitable annual charges for the use of common sewers" in 1892,[2] and the municipality of Brockton in that state passed a sewer rental ordinance in 1894 which is still in force. In Pennsylvania, sewer rental laws have been in force in townships of the

* *Presented before the Seventh Annual Conference of the Pennsylvania Sewage Works Association, State College, Pa., September 6, 1933.*

first class since 1901. At least thirty-five states have adopted such laws or have constitutional situations which enable municipalities to adopt this system of financing. In 1931, 328 municipalities had ordinances providing for sewer rental, rates and charges, and this number has undoubtedly increased since that date. Texas appears to be the leader in this movement, and in that state, according to a special release of the Texas League of Municipalities on July 20, 1932, 212 communities were financing sewer services in this manner. Ohio is also making extensive use of the rental system which has the support of the State Department of Health. The best sources of information reveal that about twenty-five Pennsylvania municipalities have adopted the system in some form. The idea has been somewhat slow in developing, but is undoubtedly gaining in popularity, as necessity for the treatment of sewage is becoming more pressing and the financing of large projects becoming more difficult. The aid offered by the Federal Government in financing self-liquidating projects, through the Reconstruction Finance Corporation and the NRA, has materially spurred states to enact sewer rental laws during the last year. Sewer rental laws may, therefore, be safely said to be no longer in the experimental state. The only question, it seems to me, which faces public authorities considering their adoption, is whether the placing of sewerage systems and treatment works on a self-sustaining basis offers a more just and equitable system of distributing costs, and a more sure and stable source of revenue, than general taxation and special assessments.

The old method of depending on gravity to assure a flow, and streams and rivers to purify sewage by dilution, involved very little expense of maintenance, if a sewer was properly constructed. The health, comfort and convenience of the people of the sewered town was, in many cases, adequately served by such methods; and as the benefit was to the entire community, the cost, over and above that which was assessed as benefits, was properly met by general taxation. But as the amount of sewage poured into the streams increased, the necessity of treatment to protect other communities became imperative and a new method of financing, the sewer rental, was devised.

The primary purpose of sewer rental laws is to provide a practical and continuing means of financing the maintenance and operation of a sewerage system and treatment works, and secondarily, to provide revenues for the amortization of indebtedness incurred at the time of the original construction and the payment of interest thereon. These laws, generally permissive in character, give municipal authorities an optional system of financing a sewerage system by means of which exact costs are reflected and not merged in the general tax levy. The people are in this manner made conscious of the cost of installing and operating a modern sewerage system.

The reason for the enactment of any sewer rental law is, of course, to confer adequate power on the municipality to collect from users of a sewerage system an annual or other periodic rental, rate or charge, to pay for the maintenance and operation of the sewerage system, to establish a depreciation fund, and to provide revenues to pay interest on and retire bonded indebtedness. Some state laws include most of the above purposes, while others are limited to the expenses of operation, maintenance and repair, including interest on indebtedness. Most of the other provisions of these laws are concerned with the dedication of the revenues, with methods of collection and procedure, and with the issue of revenue bonds, imposing no municipal liability, but depending upon sewer rentals for their repayment.

Pennsylvania Laws

The first law adopted in Pennsylvania was for townships of the first class.[3] It provided that persons connecting with a township sewer should pay, in addition to the costs of making connection, "such monthly or annual rental as shall be prescribed by ordinance." This provision is now part of the First Class Township Law[4] and has been extended to townships of the second class.[5]

By an Act of 1917,[6] boroughs were authorized to impose sewer rentals, and in 1925[7] substantially similar provisions were enacted for cities of the third class. The present law for boroughs is contained in the General Borough Law[8] and for cities of the third class in the Third Class City Law.[9] Cities of the first and second class have no statutory authority to collect sewer rentals.

The rental law for cities of the third class provides that "whenever any city has constructed any sewer, or sewer system, or sewage treatment works, either wholly or partially at public expense, or has acquired the same at public expense, such city may provide by ordinance for the collection of an annual rental or charge for the use of such sewer, sewer system or sewage treatment works from the owners of the property served by it."[10] This provision, by the use of the words "has constructed" implies that the collection of sewer rental shall not be commenced until the sewer has been completed and is in operation. The ordinance may, of course, be enacted as a part of the procedure to establish a system, but may become effective only when the sewer is placed in operation. The charge may be made, whether the cost of the original construction was paid for wholly or partially at public expense, recognizing that where part of the cost of construction was collected by special assessments against abutting properties benefited, the rental may, nevertheless, be imposed. In the case of the public acquisition of a private system, as by purchase or condemnation, the rental may be imposed only where the acquisition was wholly at

public expense. This provision needs amendment since the Third Class City Law[11] allows these municipalities to acquire private sewers and assess abutting property for the cost thereof equal to the benefits received. In such cases the acquisition, of course, would be only partially at public expense. The rental system may be established only by an ordinance and a resolution would not be sufficient. The rental or charge is imposed for the use of the sewer system in the same manner as a charge is imposed for the use of electric current or water furnished by a public utility or municipality. It may, however, be collected only from the owners of the property served by the sewer system. This raises the interesting question whether it may be legally collected from the owner of the vacant lot along which a sewer has been constructed. The rental is imposed for the use of a sewer and it is to be paid by the owner of property served by it. This language implies the idea that it may not be collected from the owner of a vacant lot, since the owner makes no actual use of the sewer and, at least for the time being, receives no service from it. There is actually no discharge of sewage from the vacant lot, and applying the system usually adopted to fix rentals—that is, by the amount of water consumed on the premises, or the number and character of fixtures—the measure of the rental, of course, cannot be applied. This matter of vacant lots makes it highly important that the system of special assessments for benefits and the collection of part of the original costs of construction by taxation should not be entirely surrendered where a sewer rental system is adopted.

The General Borough Law[12] is substantially the same as the provision found in the Third Class City Law, except that the clause relating to the cost of construction omits the phrase "wholly or partially at public expense" and in the clause relating to the public acquisition of a private sewer these words are inserted. It would appear that under the Borough Code, the sewer rental system may be adopted under any circumstances no matter how the original system was acquired or constructed. The difference between the Third Class City and Borough Laws is principally in the transposition of this phrase "wholly or partially at public expense," and it might be well, for clarification purposes, to apply these words in both statutes to the construction and acquisition clauses.

Any sewer rental imposed by a city of the third class "shall not exceed the amount expended annually by the city in the operation, maintenance, repair, alteration, inspection, depreciation or other expense in relation to such sewer, sewer system or sewage treatment works, and may include interest on money expended by the city in the construction or acquisition of such sewer, sewer system or sewage treatment works. The said annual sum shall be apportioned equitably among the several properties served by the city sewer, sewer system or sewage disposal plant."[13]

The Borough Law[14] has exactly the same provisions except that the

words "sewage treatment works" are not found therein. However, it seems to follow that a treatment works is a necessary and integral part of a modern sewerage system, and that if a borough should construct such a public work and impose an annual rental for its operation and maintenance, authority would exist under this section for such a charge. The Borough Law might well be amended to include these words to eliminate all doubt.

The provisions of both laws seem to be entirely adequate to impose any charge whatever in connection with a sewerage system including depreciation, except the capital costs resulting from the original improvement; and it seems to me advisable to amend these laws so as to enable these municipalities to include capital charges within the rentals. Specific provision is now contained in both laws for the inclusion within the rentals of interest charges on original investments. Both codes require that the sewer rental shall be equitably apportioned among the properties served by the system, which language is extremely flexible and enables the municipalities to adopt any system or combination of systems of measuring the rental they choose, so long as the burden is distributed on an equitable basis, which, I take it, implies a consideration of the benefits received by the property served, and that received by others, or the difficulties involved in the treatment of the sewage.

Other provisions of the Third Class City Law[15] and the General Borough Law[16] relate to the manner in which the rentals shall be collected. Councils are authorized to execute warrants authorizing the collection of rentals or charges by the officer empowered to collect the same. The sewer rentals are liens on the property against which charged from the date set forth in the ordinance, and if not paid after thirty days' notice may be collected by action of assumpsit or by the filing of liens in the nature of municipal liens.

The terms of the law applying to townships are broad and not hedged about by any details. They simply confer power to impose such monthly or annual rental as shall be prescribed by ordinance. In an article in THIS JOURNAL[17] Grant M. Olewiler of Lower Merion Township, in setting forth the experiences of that township with the sewer rental law, includes in the annual charge a sufficient amount to pay interest and sinking fund charges, and, incidentally, he points to the necessity of creating sewer districts in a township, and, to the injustice of the collection of capital costs by a general tax levy.

The Distribution of Costs

In their article on "Sewer Rentals and Charges," Childs and Schroepfer[18] express the opinion that the rates or charges are best limited to maintenance and operation costs because this enables municipalities to keep rentals at a low figure, and requires the installation costs to be paid by general

taxation, which they consider just, since even vacant property is benefited and increase in valuation by the construction of such an improvement. Greeley, in his article on "Sewer Rentals and Charges,"[19] holds that a sewerage system is a benefit to the health of the whole community and that consequently some proportion of the cost should be paid by general taxation, but that a sewer laid by a man's land is a special benefit for which a sewer rental charge is just and equitable.

The same view was expressed by the Governor of Pennsylvania in his veto of Senate Bill No. 213, passed at the Legislative Session of 1933. This bill, rather carefully framed, but probably somewhat inadequate to accomplish the full purpose of a sewer rental law, as this study leads me to believe, was intended as a general sewer rental law for the State and to enable municipalities to construct sewer systems and treatment works as self-liquidating projects, and thus receive the benefit of Federal appropriations available at that time through the Reconstruction Finance Corporation. This bill not only authorized rentals sufficient to pay the expense of operation, maintenance, repair, alteration, inspection, depreciation or other expense of a sewer system and treatment works, but also sufficient to provide for the amortization of indebtedness and interest thereon, and sufficient to establish a margin of safety of ten per cent, any surplus over the margin of safety being required to be paid into the sinking fund. The Governor objected to the inclusion of annual capital charges in such rentals and concluded such charges should be paid by special assessments and general taxation. However, it is interesting to note that a number of states adopted laws during 1933 providing that both principal and interest might be paid from sewer rentals in order to make projects self-liquidating.[20] In North Dakota provision was made for the payment of sixty per cent of the original cost by sewer rentals and forty per cent by taxation.

In the end, the adoption by any municipality of a sewer rental system should be, first, in the interest of equity and justice and, second, to secure an adequate and continuing revenue to assure efficient operation at all times. It is poor economy to construct expensive sewerage systems and treatment works without adequate means of financing their operation and maintenance; and experience frequently shows that when municipalities face the necessity of curtailing expenditures, the operation of the sewerage system is the first to be crippled. This is a natural step. Although citizens are directly interested in the quality of the water supplied, they have little interest in sewage other than to be assured that it is removed from their premises. They are not much concerned with the rights of riparian users upon whom their sewage is dumped. Consequently, when maintenance funds for the treatment of sewage are reduced to aid in cutting the annual tax levy, there is no public concern. The installation of the sewer rental system tends to overcome this difficulty.

That it is unjust to require unserved property to bear an equal portion of the cost of construction, maintenance and operation of a sewerage system and treatment works is apparent to the most casual student of governmental costs. To the writer this is the most important argument in favor of a sewer rental system. It certainly would not be just to pay the light bills of citizens of a community by means of general taxation, and there is very little actual difference in paying the sewer bills in such a manner. If the enabling laws permit, there is no reason why a sewer rental system should not be used in combination with special assessments for benefits and general taxation, thus installing a plan where costs are equitably distributed among all property within a municipality. The burden of capital costs, operation, maintenance and depreciation should be distributed commensurate with the service rendered and benefits specially and generally received.

Three general items of expenditure should be considered: First, original or capital costs; second, operation and maintenance; and, third, depreciation. To meet these costs three systems are available: sewer rentals, special assessments and general taxation. We are all familiar with the rule of law that not all of the original cost of a sewerage system may be collected by special assessments for benefits from property abutting or served, but only so much as represents the cost of a branch sewer sufficient to give it all the benefits it enjoys.[21] A large part of the cost of trunk and intercepting sewers cannot be specially assessed, either by the benefit or foot-front rule; and in Pennsylvania is generally paid for by means of bond issues supported by taxation. A lateral or branch sewer is of special benefit to the property along which it runs and the cost thereof, together with the cost of connections, may legally and equitably be assessed against such property as benefits. The original cost, above the cost of the lateral sewers and connections, undoubtedly represents a greater benefit to the served than the unserved property, and equitably a portion of this cost, together with interest, may be collected by sewer rentals, the remainder being met by means of taxation, on the theory that the improvement is a benefit to the general health of the community, and that ultimately the same system will be extended to unserved property. On the other hand, operation, maintenance and depreciation may equitably be required to be paid by means of sewer rentals. Such a system, briefly stated, would provide for the payment of the original cost of the improvement and interest on indebtedness partly by special assessments, partly by general taxation and partly by sewer rentals, while operation, maintenance and depreciation would be financed entirely by sewer rentals. The division of the carrying charges of the original investment between the three systems proposed for payment is, of course, an engineering matter and no doubt an equitable division can be arrived at.

Such a system, it seems to me, meets sufficiently the viewpoint of those who contend that the collection of construction costs by means of sewer rentals is unjust. Of course, that which has been said on this point is rather speculative in this State and for consideration in the future, since, at least as to cities and boroughs, the present statute law does not authorize the collection of sewer rentals for capital charges, but is limited to operation, maintenance, depreciation and interest on indebtedness. As pointed out above, in some of the townships of the first class, under the existing law, the capital charges in excess of the amount realized from special assessments are being collected by means of sewer rentals. This is probably a fairer method for such communities, since a large part of the territory of these municipal units consists of farm lands and wood lots not located within the sewer district and the creation of sewer districts is necessary. Their situations cannot be compared to cities and boroughs where the population is denser throughout the whole municipal area and farm lands are negligible.

The Measure of the Rental

In their study of sewer rental laws, Childs and Schroepfer[18] list eighteen different methods of making charges for sewer service which were found to be in force. One-half of these are based partly or entirely upon the amount of water consumed, while the other half are based on factors independent of water consumption. In some cases the rental is measured solely on the basis of water consumption, or by charging a percentage of the water bill; in others, water consumption is combined with assessed valuation, general taxation or other factors. Water consumption, or a percentage of water bills, is usually the basis for the rental where the water plant is municipally owned and the water metered. Authorities generally agree that this is a fairly accurate measure of the use made of a sewer system. Where the amount of water consumption is not available, the number and character of water fixtures are frequently used to measure the rental.

Financing

One other matter which should be taken into consideration is the question of financing any sewerage system. Where a rental is imposed to collect interest and sinking fund charges, in whole or in part, relief from these capital charges follows in the annual tax levies, which is, of course, immediately reflected in the individual's tax bill. The Third Class City Law[22] contains provisions that in making an improvement where the cost thereof is to be paid by assessments, in whole or in part, upon abutting property, the city may issue assessment bonds, or as called in other states, revenue bonds, based solely upon such assessments and imposing no

municipal liability. In Pennsylvania there is no authority for the issue of non-debt bonds for the reason that a sewer rental system has been established to pay carrying charges; and as pointed out above, sewer rentals may not be imposed in cities for the payment of sinking fund charges, but only interest thereon. The same legal situation with respect to sewers prevails in boroughs.[23] In townships apparently sewer rentals are imposed to meet interest and sinking fund charges, but no authority exists to issue so-called improvement or revenue bonds which impose no municipal liability.

There undoubtedly is a question whether, under the Pennsylvania constitutional situation, the Legislature may legally authorize the issue of so-called revenue bonds, supported wholly by sewer rentals and imposing no municipal liability—that is, not decreasing the borrowing capacity of the municipality. While so-called assessment or non-debt bonds, supported wholly by municipal liens, entered against abutting property benefited by a street or sewer improvement, have been upheld by the lower courts,[24] the Supreme Court has held that an act[25] authorizing the issuing of non-debt bonds for the acquisition of water works to be supported by water rates was unconstitutional, and that such bonds could only be issued as debt bonds.[26] Of course, this situation was corrected in some measure by the constitutional amendment of 1913,[27] which authorized the issue of non-debt bonds, supported by water rates, where water works were acquired or originally constructed, but as to sewers the situation remains unchanged. It is evident that in case law a distinction exists between assessment bonds supported by municipal liens, which are at all times quick assets, and those supported by continuing revenues like water rates and sewer rentals. In the one case the assets are in hand, in the other they depend on future collections.

In constructing a sewerage system, the municipal authorities must therefore bear in mind that bonds issued to pay original construction costs will create a municipal indebtedness, except such as are issued in cities and boroughs as improvement or revenue bonds, equaling, but not exceeding, the amount specially assessed against abutting property benefited; and that at the time of the creation of the debt, a tax must be levied for the life of the bonds, sufficient to pay interest and sinking fund charges on all debt bonds.[28] However, where some of the carrying charges of these original costs are provided for by a sewer rental charge, as, for instance, interest in third class cities and boroughs, or interest and sinking fund charges in townships, the tax, as originally laid, may, undoubtedly, be decreased from year to year, as the rental revenues set aside and paid into the sinking fund make the imposition of the total levy unnecessary. The reduction in the tax rate, pointed to above, may thus be accomplished; but with the one exception noted, the borrowing capacity of municipalities

will necessarily be affected by the bonds issued. The present tendency in other states, undoubtedly, is to issue revenue bonds to be retired by the sewer rentals, and this is a point to be seriously considered in the future in this State, and if constitutional amendment is required, action should not be delayed beyond the legislative year of 1935.

Conclusion

I trust that this discussion has indicated that the installation of a sewer rental system in cities of the third class, boroughs and townships is feasible and practical under existing laws, and not wholly experimental. However, amendments may well be made to these laws which will improve them and aid in establishing a sounder basis for the application of the rental revenue.

Authorities, of course, agree that the system may be best applied at the time when a system is first being constructed. However, it may be applied at any time if the municipal authorities find there is sufficient sentiment to support such a move. There are many arguments in favor of the system and other arguments against it. Those who desire to weigh them are again referred to the Childs and Schroepfer article to which I have referred several times. A reading of this article by those interested will well repay the effort. It is by far the best study of the subject and exhausts every practical detail.

References

[1] October, 1932.
[2] General Laws, Chap. 83, Sec. 16.
[3] May 24, 1901, P. L. 294.
[4] May 24, 1931, P. L. 1206, Sec. 2401.
[5] May 1, 1933, P. L. 103, Sec. 1501.
[6] July 6, P. L. 704, Sec. 15.
[7] May 4, P. L. 512.
[8] May 4, 1927, P. L. 519, Secs. 2170–2173.
[9] June 23, 1931, P. L. 932, Secs. 3211–3214.
[10] June 23, 1931, P. L. 932, Sec. 3211, as amended by Act No. 175 approved May 22, 1933.
[11] Secs. 3220–3222.
[12] May 4, 1927, P. L. 519, Sec. 2170.
[13] Sec. 3212.
[14] Sec. 2171.
[15] Secs. 3213–3214.
[16] Secs. 2172–2173.
[17] THIS JOURNAL, **4**, 300 (March, 1932).
[18] *Ibid.*, **4**, 1006 (November, 1932).
[19] *Municipal Index* (June, 1932).
[20] Oregon, Chap. 290, 1933; North Dakota, 1933, Chap. 179; Illinois, 1933, Senate Bill 245; Idaho, 1933, Senate Bill 246; West Virginia, 1933, House Bill 29; New Jersey, 1933, Senate Bill 188; Maine, 1933, Chap. 251.

[21] Park Avenue Sewers, 169 Pa. 433.
[22] 1931, June 23, P. L. 932, Sec. 2705.
[23] 1927, May 4, P. L. 519, Secs. 2140–2149.
[24] City of Chester v. Woodward, 33 Dauph. 59.
[25] May 31, 1907, P. L. 355.
[26] Lesser v. Warren Boro., 237 Pa. 501.
[27] Art. IV, Sec. 15.
[28] Constitution, Art. IX, Sec. 10.

[EDITOR'S NOTE: Discussion of Mr. Fertig's paper received too late to be included in this issue, will be published in the January issue.]

Revenue Bonds and Sewer Service Charges at Bloomington, Indiana*

BY CARL B. CARPENTER

City Engineer

Some months ago, the City of Bloomington adopted by ordinance a schedule of sewer service rates or charges as part of the legal procedure necessary in anticipation of the construction of a new sewage treatment works, under the provisions of the Indiana Sewer Service Charge and Revenue Bond Act, as contained in Chapter 61 of the Acts of the General Assembly, Special Session, 1932, and as amended by Chapter 187 of the Acts of the General Assembly, Regular Session, 1933.

The Indiana Sewer Service Charge and Revenue Bond Acts.—Under the provisions of the Acts, along with the assistance of other existing statutes, it is possible for Indiana cities and towns to construct new sewage disposal works, the cost of which is payable solely from sewer service charges. The total revenues derived from the service charges are applicable to the entire cost of the works, including fixed charges as well as operation, repair, replacement and maintenance expense. To meet the cost of construction, provision is made for the issuance of revenue bonds, dependent entirely for their security upon anticipated revenues from service charges.

The Acts require that the rates or charges must be sufficient in each year for the payment of the proper and reasonable expense of operation, repair, replacements and maintenance of the works, and for the payment of sufficient sums into a sinking fund, to: (1) meet the cost of interest when it becomes due; (2) provide for the necessary fiscal agency charges for paying bonds and interest; (3) provide for the payment of bonds as they fall due; and (4) provide a margin for safety and for the payment of premiums upon bonds by call or purchase, as elsewhere provided therein, which margin, together with any unused surplus of such margin carried forward from the preceding year, shall equal 10 per cent of all other amounts so required to be paid into the sinking fund.

The further provision is made that such required payments shall constitute a first charge upon all net revenues of the works. After the payment into the sinking fund, as indicated above, there is the provision that the authorities designated in the Acts may transfer all or any part of the balance of net revenues, after reserving an amount deemed sufficient for operation, repair and maintenance for an ensuing period of not less than twelve months and for depreciation, into a sinking fund or into a fund for extensions, betterments and additions to the works.

* *Presented at the Sixth Annual Conference of the Central State Sewage Works Association, Indianapolis, Ind., Oct. 13, 1933.*

The Acts provide, also, that the bonds shall contain a statement on the face that the city shall not be obligated to pay the same or the interest thereon, except from the special fund provided from the net revenues heretofore mentioned.

The Indiana Supreme Court Decisions on Revenue Bonds.—The Indiana Supreme Court has held that the issuance of revenue bonds does not constitute the incurring of a debt by the municipal corporations within any state constitution or statutory provisions or limitations;[1] also, that revenue bonds or other like obligations, issued for the construction of extensions or improvements to an existing municipally owned revenue producing utility, when made payable from and secured by a pledge of the revenues of the existing utility, as extended or improved, do not constitute a debt of the municipality.[2]

Former Methods of Financing Sewerage Improvements.—In Indiana, heretofore, the common method of meeting the cost of sewage disposal works has been by the issuance of special assessment bonds against the lots and lands within an affected drainage area, or by the use, directly or indirectly, of general obligation bonds. The cost of operation and maintenance was generally included as part of the municipal tax levy.

During the past, in Bloomington, the cost of sewerage improvements has been met by special assessments against the lots and lands within a drainage area. After general taxes, the special assessment taxes were a first lien upon the individual properties assessed and benefited. The special assessment bonds were issued and delivered directly to contractors in payment on contracts and the city was not obligated in any manner except as acting in the capacity of fiscal agent. The methods of distributing costs usually did not recognize the intensity of use of land area, nor the resultant effect of quantity or character of sewage contributed, per unit of area. Being mindful of the injustices occasioned in the methods used, Bloomington citizens have received in a favorable manner the proposal for sewer charges, which tend to agree more nearly with services received.

General Local Information.—The estimated total population of Bloomington, including a student population at Indiana University of about 3500, at present is about 23,000. Although there are several large industries, there is but a negligible contribution of industrial wastes, so that practically the entire sewage flow is that from residential users.

Because of a closely underlying formation of solid limestone, along with the rugged topography of the area, the use of the existing system of gravity operating sanitary sewers has been restricted to part of a large central valley, surrounded on three sides by pronounced drainage divides. The original system of sewers laid out more than twenty-five years ago has been enlarged successively so that approximately fifty per cent of the city's total area of about 2250 acres has been provided with sanitary

sewers. The present system, however, is not provided with adequate intercepting and outfall sewers. The sewage treatment works, also built several years ago, are disadvantageously located and are inadequate for present needs.

Proposed Improvement.—The sewerage improvement contemplated for construction under the new Revenue Bond Acts includes the essential portions of a general comprehensive plan of sewers, for an ultimate population of more than two and one-half that at present. The sewage treatment plant, to be located more than one and one-half miles farther from the city than the existing plant, is designed to provide complete treatment for estimated sewage flows at the end of an approximate fifteen-year period. The plant units are to consist of mechanically cleaned bar screens, grit chambers, primary settling tanks with sludge removal equipment, skimming and degreasing system, automatic dosing tanks, trickling filters, final settling tanks with provisions for sludge removal, separate sludge digestion tanks, gas collecting system, sludge heating and digestion control appliances, glass covered drying beds and all necessary facilities and equipment, including office and laboratory. The plant will be served by outfall sewers connecting the entire present sewered district. An outfall sewer, pumping station and necessary force main is included to deliver sewage from a built-up outlying valley beyond the drainage divide, north of the present sewered area. With the exception of the pumping just referred to and the pumping of sludge at the treatment plant, the entire system is designed to operate by gravity.

The estimated cost of the improvement is $495,000, of which approximately 40 per cent is for the construction of more than two miles of interceptors and outfall sewers as well as an outfall sewer extension approximately two miles in length.

Sewer Service Charges Established.—The sewer service rates finally established take into consideration only those water services at present connected to the sanitary sewers. The ordinance fixing rates was made with the full realization for the probable need of meeting many individual problems to be determined after actual use. For this last reason, the ordinance given below, which conforms to the Acts under which it is to operate, provides for an amount of elasticity, without jeopardizing the rate schedule included.

Extract from an ordinance fixing the schedule of rates or charges to be collected by the city of Bloomington, Indiana, from the owners of property served by the sewage disposal plant and works of said city. (Adopted May 29, 1933).

Section 1. Rates and charges shall be collected for the use of and the service rendered by said sewage disposal works, from the owners of each and every lot, parcel of real estate or building that is connected with and

uses such sewage disposal works by or through any part of the sewerage system of the City, or in any way uses or is served by said sewage disposal works, which rates or charges shall be payable as herein after provided, and in amount determinable as follows:

(*a*) The rates shall be based upon the quantity of water used on or in the property or premises subject to said rates or charges, as the same is measured by the City Water Meter there in use. (Figure 1.)

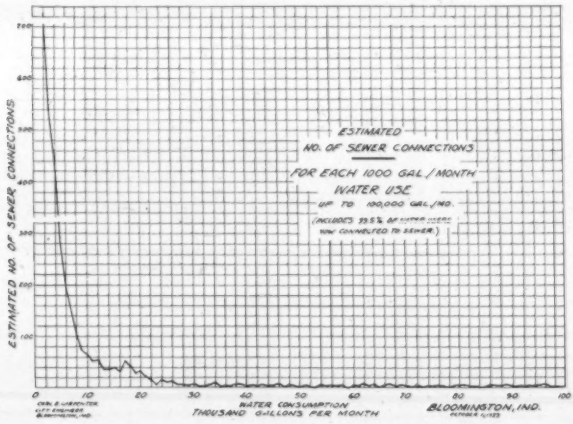

FIG. 1.

(*b*) The schedule on which the amount of said rates or charges shall be determined shall be as follows:

First 2,000 Gallons	$0.125 per 1000 Gallons
Next 3,000 Gallons	0.10 per 1000 Gallons
Next 5,000 Gallons	0.09 per 1000 Gallons
Next 10,000 Gallons	0.08 per 1000 Gallons
Next 30,000 Gallons	0.07 per 1000 Gallons
Next 50,000 Gallons	0.06 per 1000 Gallons
Next 100,000 Gallons	0.05 per 1000 Gallons
Next 150,000 Gallons	0.04 per 1000 Gallons
Next 250,000 Gallons	0.03 per 1000 Gallons
Over 600,000 Gallons	0.02 per 1000 Gallons

(*c*) Water which is used in process of manufacture or for any other purpose which does not discharge to the sanitary sewers shall be exempted, provided, however, that the property owner shall install the necessary

meters to indicate the amount of water used which does not discharge into the sanitary sewers.

(*d*) In the event a lot, parcel of real estate or building discharging sanitary sewage, water or other liquids into the sanitary sewerage system of the City, either directly or indirectly, is not a user of water supplied by the City, and the water used thereon or therein is not measured by a city water meter or by a meter acceptable to the City, then the amount of water used shall be otherwise measured or determined by the City in

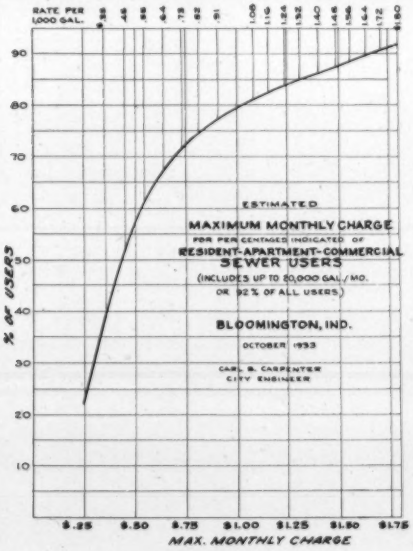

FIG. 2.

order to determine the rate or charge provided for in this ordinance, or the owner or other interested party, at his own expense, may install and maintain a meter acceptable to the City for said purpose.

(*e*) In the event a lot, parcel of real estate or building discharges sewage in the form of industrial waste either directly or indirectly into the City sanitary sewerage system and the City finds that it is not practical to measure such wastes by meter, it shall measure the same in such manner and by such methods as it may find practical, in the light of the conditions

and attendant circumstances of the case, in order to determine the rate or charge according to the corresponding rates per thousand gallons provided in this ordinance.

(*f*) Such rates and charges shall be billed monthly and shall be due and payable on or before the tenth day of the calendar month next succeeding the date of the billing.

(*g*) The minimum rate or charge for any service shall be 25 cents per month.

Average Sewer Service Charges in Bloomington.—As indicated in Figure 2, the charge for 52 per cent of all sewer users is 45 cents per

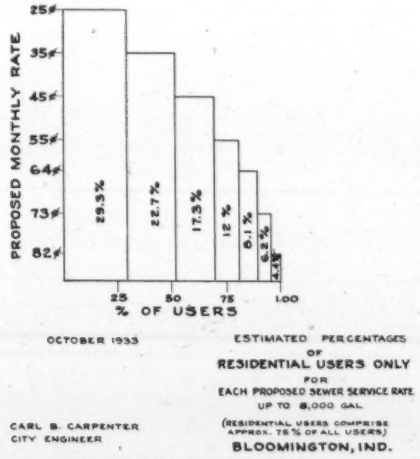

FIG. 3.

month, or less; for approximately 75 per cent of all users, 82 cents per month or less. Referring to Figure 3, which considers residential connections as a complete unit, the charge for 52 per cent of such users is 35 cents or less per month. Approximately 70 per cent of the residential users will pay not to exceed 45 cents per month.

Comparison of Water and Sewer Service Charges.—The Indiana Sewer Service Charge and Revenue Bond Acts do not in any manner preclude a definite relation between sewer and water service charges. The Acts do require, as mentioned above, that the rates or charges must be sufficient in each year for the payment of all fixed charges as well as the reasonable

cost of operation and maintenance of the works. The probable relation between water and sewer service charges, in different communities, would therefore be in variation, depending among many other factors upon the water rate schedule, the extent of sewage disposal works costs included as fixed charges, as well as the length of the sewerage bond issue. Figure 4 was made for the purpose of comparing the water and sewer service charge in Bloomington. From Figure 4, it may be noted that for the minimum or 2000 gallon per month group, which includes 22 per cent of all sewer

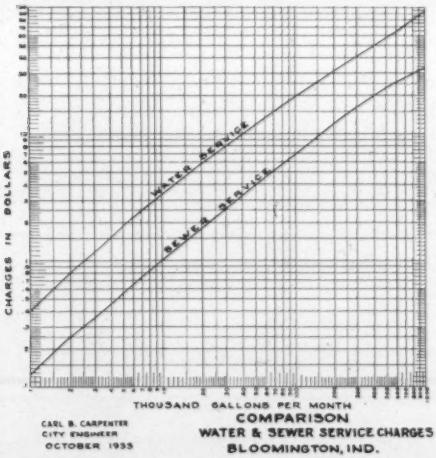

FIG. 4.

connections, the sewer charge is 25 per cent of the water service cost. The maximum for residential users is about 30 per cent. For 99.5 per cent of all sewer users, the sewer charge is a maximum of 35 per cent of the water service amount.

References

[1] Case of Fox. *vs.* City of Bicknell, 193 Ind. 537, 141 N. E. 222. Case of Underwood *et al.*, *vs.* Fairbanks, Morse Company, *et al.*, 185 N. E. 118 (not yet published in Indiana reports).

[2] Case of Underwood, *et al.*, *vs.* Fairbanks, Morse Company, *et al.*, 185 N. E. 118 (not yet published in Indiana reports).

Delinquencies in Sewer Service Accounts*

BY W. W. MOREHOUSE

Director, Department of Water and Sewage, Dayton, Ohio

The idea of operating sewer systems as a public utility is not new. A private plant has been operated at Atlantic City for some years and I was quite surprised to learn some years ago that numerous plants had been built by private engineers and contractors for cities in the southwest. These were operated as private utilities until such time as the municipalities had seen fit to take them over. The funds for operating these utilities were billed against and collected from the owners of connected property.

The Ohio Sewer Rental Law was passed April 5, 1932, by the Ohio Legislature. It gave municipalities the right to operate their sewer systems with money collected directly from owners of connected properties, instead of being obliged to look to the taxing bodies. The intent is to collect in proportion to the service rendered. The Act makes these Sewer Rental Charges a lien upon the property served and if not paid when due they shall be collected in the same manner as other city or village taxes, *viz.*, by being certified to the county auditor and placed upon the tax duplicate for collection.

The Act also specifies the manner in which the sewer system shall be administered and specifies very clearly how the money shall be spent and what it shall be spent for. It must be kept as a separate and distinct fund and shall be used for the payment of the cost of the management, maintenance, operation and repair of the sewerage system and sewage pumping, treatment and disposal works, and any surplus may be used for the enlargement or replacement of the same and for the payment of any interest on any debt incurred for the construction of such sewerage system and sewage pumping, treatment and disposal works, and for the creation of a sinking fund for the payment of such debt, but it may not be used for the extension of a sewerage system to serve unsewered areas or for any other purpose.

The city's administration ordinance places the operation and maintenance of the sewer system, the construction, operation and maintenance of the sewage pumping stations, sewage treatment plant and water works, as well as the billing and collection of water and sewage accounts under a director in the department of water. The sewer maintenance is in charge of a superintendent as is also the treatment plant. The director has general supervision over the department and acts as superintendent of the water works and has supervision over the billing and collection of accounts both for water and sewer service.

* *Presented before the Sixth Annual Meeting of the Central States Sewage Works Association, Indianapolis, Ind., October 13, 1933.*

The sewage rental accounts are based on the amount of waste discharged to the sanitary sewers and are arrived at, except in special cases, by the amount of water registered on the water meter. Water used for processing or which for any reason does not go to sanitary sewers is not charged for, but water from private water systems which does go to the sanitary sewers is estimated and charged for. Some large estates have sprinkling systems for lawns and shrubbery, have installed separate services and meters for these systems and are not charged for sewer rental on these meters.

The main reason for combining the sewer and water department was economy. The billing and collection machinery was already set up for the billing and collection of water accounts and only needed expanding to take care of sewer service. The combined bills can obviously be made at less expense than two separate ones.

The foregoing remarks have seemed probably to refer to everything but delinquencies in collections, but as this is a discussion of the results of the experience of one municipality it is almost necessary to have the background to get the resulting picture as we have found it.

Billing for sewer service is done in connection with the regular billing for water for the several districts and is billed quarterly by the regular water works forces. The billing for sewer service is added as a second amount on the water bill and is collectable at the same time. If the bill is not paid on or before the last discount day, the consumer loses his discount and if not paid ten days later a 5 per cent penalty is added.

If for any reason a consumer decides that he isn't going to pay his sewer service charge it is taken off the water bill at his request and the sewer charge is set up as delinquent. The owner is then notified and if it still remains unpaid it is certified to the county auditor. This is supposed to be done thirty days after each penalty period but the county auditor will only accept certification once a year. This is the first Monday in September. About one month before this date personal letters are sent to all owners who have delinquent bills against them. Then if nothing is heard from them it is finally certified to the county auditor. This procedure has brought the delinquent accounts down to a very small minimum.

We have been operating the sewer service rental for five years and our record of delinquent accounts is as follows:

Year	Delinquent Notices Delivered	Certified to County Auditor	Amount Certified	Total Collection
1929	250	116	$340.90	$211,368.96
1930	300	2	22.96	231,272.69
1931	350	11	94.80	241,636.08
1932	390	28	208.27	233,929.03
1933	465	134	1244.85	

The total amount of sewer service accounts are about 48,500. The percentage of delinquent notices have varied from one-half of one per cent to almost one per cent, accounts actually certified range as high as 0.31 per cent and the amounts of delinquencies required to be certified from less than 0.01 to 0.53 per cent.

During the present year the percentage of delinquents has been very much higher both in sewer and water accounts.

Another thing that has reduced delinquencies to some extent has been the practice for the last two years of allowing consumers who absolutely cannot pay water or sewer accounts to work sufficient time to liquidate at least a part of his bill. These are all investigated thoroughly as to their right to this concession.

The reason back of this is that almost every residence is connected to the sanitary sewer and there are very few wells in residence property and if water was shut off for non-payment an unsanitary condition would have been the result in many cases.

This "work account" has amounted to approximately $750 per month for the past year for sewer service bills. This practice was started to take care of emergency conditions and will be discontinued eventually.

The main concern of the department is to take care of those actually entitled to the service and to eliminate chiselers.

There is a valid argument in favor of sewer rental instead of a direct property tax for funds to operate sewage systems. Most people will pay for service rendered if it is properly shown that it is a service and that the charges are fair. It is also due in smaller installments, which is helpful.

In our particular case the combination of sewer and water bill has helped to a marked extent in the collection of the sewer service charge, for it has been tied up with a service to which the consumer has been accustomed for some time.

Finally, the collection of sewer service bills and the elimination of delinquents, like the collection of water bills and all other bills, requires an active office force with plenty of ideas.

Selling Sewage Treatment*

BY GUS H. RADEBAUGH

Manager, Urbana and Champaign Sanitary District, Urbana, Illinois

State sanitary engineers in Illinois, Indiana and Wisconsin reported in 1932 to the National Committee for Trade Recovery the total cost of needed sewage works that were being held up because of the poor market for bonds. At that time it was stated that these projects could be made self-liquidating and eligible for loans from the Reconstruction Finance Corporation. Illinois reported total costs of projects amounting to $63,095,000, Indiana, $15,000,000 and Wisconsin, $1,250,000. Illinois, Indiana and Wisconsin have a combined population of 13,808,163 (1930 census), which represents a per capita expenditure on possible sewage treatment projects of $5.74 for each man, woman and child in these three states for health insurance and a self respect that means so much to all of us.

National Recovery Act.—Much is being stated in the press and from the platform in regard to the immediate expenditure of public money for public work to relieve the unemployment situation. The National Industrial Recovery Act, passed in the 73rd Congress, has for one of its objectives the immediate starting of public work. Sewer and sewage disposal projects are eligible for a Federal grant of 30 per cent of the cost of the labor and material employed upon such projects.

To set up more clearly the executive structure through which this gigantic governmental undertaking is controlled, the details are reviewed rather briefly.

Under the National Industry Recovery Act, Title II, Public Works, the President created the Emergency Administration of Public Works. Under this agency a State Advisory Board is set up in each state to stimulate the submission of projects, to inform the public of the classes of projects eligible for the benefit of the act*** promptly to submit to the Administration with its recommendations, all projects considered.

Much can be accomplished in the building of sewage treatment projects all over our country if those communities interested desire to take advantage of the 4 per cent loans made possible through the Federal Emergency Administration of Public Works.

Estimate of the cost of the project must be subdivided into principal items, in sufficient detail to permit checking, showing separately the following subtotals:

1. Preliminary expenses;
2. Cost of land, rights of way and easements;

* *Presented before the Sixth Annual Convention of the Central States Sewage Works Association, Indianapolis, Indiana, October 13, 1933.*

3. Construction cost, subdivided into principal structures or classes of work, and showing (i) labor and (ii) material cost for each subdivision;
4. Engineering charges;
5. Legal, administration and other overhead charges;
6. Interest during construction;
7. Miscellaneous costs, in reasonable detail.

All those interested in taking advantage of this Act to secure an outlet for the necessary bonds to finance a project at a 4 per cent interest rate should become acquainted with Circulars Nos. 1 and 2 of the Federal Emergency Administration of Public Works. These circulars can be secured from your State Advisory Board.

Analysis of Promotional Programs.—It has always been my opinion that a successful outcome will result from any promotional program only when all the difficulties, as well as the benefits, are properly analyzed. I hesitate somewhat in reviewing some of the difficulties that I understand are causing considerable concern in a number of our communities.

1. Some of our smaller communities are reluctant to take advantage of this act due to the scale of wages specified. I understand it is claimed that the low interest rate is more than offset by the added cost for labor.
2. Does the 30 per cent grant really mean a 30 per cent reduced cost on the project?
3. Are the engineering fees included in the grant?
4. Is the cost of the land, right-of-way, etc., included?
5. Are the attorney's fees and the consulting fees included?

It is understood that the last three items are not included in the grant. No doubt there are many other queries that have come to the attention of those closely associated with the promotion of sewage treatment in our various communities, but, after all, is the sewage treatment project promoted merely to take advantage of this act? Of course it is not. No doubt in every community where this question is being studied, the respective State Boards of Health have urged the importance of sewage treatment to the community. Sell sewage collection and treatment as the main issue as a justifiable expenditure of the taxpayers' money, and take advantage of the act for the financial setup at a 4 per cent rate, if it is decided that it is the cheapest and best method.

Pertinent Facts.—An editor in one of the larger down-state Illinois papers, in an editorial entitled "Public Works Money" presented several very pertinent facts which, in my opinion, are being very closely reviewed by the very much interested taxpayers of today. Extracts from this editorial follow:

"Lively disputes have arisen over the handling of Federal public works money, with various municipal authorities on one side, and Secretary

Ickes, in charge of distribution of the fund, on the other side. The municipal officials claim that there is too much red tape in the public works bill, and that technicalities are holding up distribution of the money. Secretary Ickes reports that the Federal Government must be careful of the distribution of the funds, and charges that municipalities have been wasteful."

"In an address at Chicago Secretary Ickes made some bold statements**** "To our surprise," he said, "we find that in many parts of the country the Federal Government is offering a grant of 30 per cent and a loan of the balance of 70 per cent at 4 per cent interest, which is being regarded as ungenerous or even a niggardly stepfather."

"Municipal authorities may be right in their contention, or Secretary Ickes may be right. No one can determine at this time who is right. But the situation brings up some interesting questions.**** The Federal Government is granting 30 per cent, and loaning 70 per cent of the money appropriated for public works. Should there be any argument there?**** If the formula were reversed, the Federal Government would be granting 70 per cent and loaning 30 per cent. That might satisfy the municipal authority and keep down the argument on that score, but it would mean nothing to the taxpayers. They have to meet the bill 100 per cent, regardless of how it is appropriated. The taxpayers have to pay back all the money, whether it is called a grant or a loan.**** There should be a better understanding by the people of what takes place when public funds are appropriated. The people should understand that they are not getting a gift when appropriations are made. They should realize that they will have to pay the bill."

Public Protection.—The above editorial has some justification on the basis of throwing a mantle of public protection around the spending of the taxpayers' money. There is no justification to build public works monuments that are not needed, and there is no need to inform the taxpayers they are getting something for nothing. The average citizen wants to pay for what he gets.

Certainly no one will deny the importance of stream sanitation, the protection of our drinking water, the protection of our health by the construction of sewage treatment projects, which with the small per capita cost need not be a tax burden on any one.

Direct relief of the unemployed in many of our population centers is still serious, and it is better, it seems to me, for the taxpayers to put men to work on public works actually needed, and that can be properly financed, rather than to merely issue a dole, which is commonly called a county order.

Taxpayers Are Interested.— During the past year it is evident that taxpayers, through their taxpayers' protective leagues, citizens' protection

associations, citizens' leagues, community protection associations, etc., are demanding a reduced taxation. The need for this relief is apparant to every one who is a taxpayer. Every effort is being presented to save the taxpayer from financial destruction. Taxpayers will deplore in the wildest terms the promotion of projects that would represent a per capita expenditure of $5.74. However, it is my opinion that a sewer or sewage treatment project that is really needed by a community, and has been approved by the State Department of Public Health as to its design, carrying also the approval of the Federal Emergency Administration of Public Works, will encounter little real opposition. Federal approval offers a possible solution of the problem of bonded indebtedness by covering the cost of the project at a 4 per cent interest rate, together with a 30 per cent grant on the cost of the labor and material. In addition, if the local program is set up with the highest ideals for honest and intelligent efforts by the citizens supporting the project, it is certain to be approved by the voters as a health protection measure that is vital to the future health conditions of the community.

Penalty of Ignorance.—It is inborn in all of us to respect cleanliness and deplore filth. This is a deeply grounded feeling of the American people. Dr. Henry Baldwin Ward, formerly National President of the Izaak Walton League of America, stated most forcibly a scientific fact that cannot be denied when he said, "Sanitation means civilization, not only success, but comfort and happiness, and even more than that, it means existence. The penalty of ignorance and carelessness comes in the form of disease, death and destruction."

Investments of Good Health.—A prominent editor, during an educational campaign for a sewage treatment plant in an Illinois town, editorially compared the cost of sewage treatment to an average property owner with that of money spent by the average individual for entertainment. In part he stated, "Yes, the bonds proposed to be issued by the community to build a sewage treatment plant will increase taxes. The payment of interest and retirement of bonds on a $10,000 resident property will cost $3.33 a year, the price of one football game or a ticket and a half to some good road show."

"Just why is it a man will get red in the face and paw the air when asked to pay $3.33 for proper sewage disposal, when he spends freely and without question ten times that amount for personal indulgence and never misses it, may be plain enough to all of us, but is just as discreditable as it is plain."**** "If we fail to do something about it, it will do something to us, and that something will not only cost us dollars and cents, but human lives. We may think to dodge the issue, but the issue will not be dodged. This proposition is a bill for services to be rendered; vital services without which we cannot proceed. The cost is moderate, if you

must think of it as cost. As a matter of fact, it is nothing of the kind, but an investment of good health, than which there is no better material investment."

Let the Truth Prevail.—None of us taxpayers will be very anxious to oppose a community health program when we, our neighbors, and the folks about town learn all the facts about the project. To sell sewage treatment, just remember, please, that a public dollar was once a private dollar in the pockets of the individual citizen who has, and should have, a lot to say about the acceptance or rejection of a community indebtedness. It is my humble opinion that the time is here, not coming, but here right now, when the old order of things "let the public be damned" is no more. If this antiquated theory does prevail, the promotion of any public project will be a complete and earned failure.

Give the citizenship all the facts. Forget the traditional habit of some of the old timers that the public should never know. If your project is not on the up and up, it should go by the board. There is absolutely no justification for any group of citizens to hold back information from the public. Remember also, please, that an informed public is a coöperative public, and much more can be accomplished by placing all the cards on the table, face up, where the banker, the baker and the candlestick maker can look them over, offer their suggestions, criticisms and what not.

We will all agree, I am sure, that it takes a certain amount of leadership, engineering ability and intelligent patience to permit a public analysis of a project, but I feel sure that good will come from such a public airing. May I take the liberty to hint that nothing but the very best engineering efforts will put over such a program. Some may take the position that the public does not know how to judge the merits of an engineering project. I will admit that some of the old boys about town will become an expert sanitary engineer overnight, but remember this please, after you have him sold, he is of tremendous importance to the future success of the project. A little time and patience with this type of citizen will often eliminate strenuous opposition to the public project.

The Engineer.—To sell sewage treatment, the engineer, to be a success, must possess two very distinct and important traits: One, he must first be an engineer who knows the basic and underlying technical problem. Second, he must be a man of sufficient vision to work with the public. In a common-sense analysis, he must be a missionary, not only of engineering knowledge, but health protection work as well. He needs also to be a diplomat, a salesman, and a community coördinator, a director general, who gets the community working and pulling together for the common cause of cleaning up the streams, not only to save the fish life, but also to insure the health and happiness of the people in the town which he is serving. The importance of promoting the health aspects of the project

instead of the "saving of the fish" idea is, I believe, becoming more widely appreciated. It is a worth while effort to save the fish for food and recreational purposes, but preservation of fish life certainly cannot be considered before safety of human life. Many times I have stated that polluted streams strike back at community health. They strike their blow through typhoid, dysentery and cholera. Health is everything, and has been too lightly considered as an important community problem in the past.

An Educational Campaign.—The protection of public health through warfare on disease, improvements and enforcement of food laws, sanitation and its relation to public health constitute one of the most important services of the press. Nobler in effect than any of the crusades of the middle ages are the efforts that the American papers put forth against disease and the promotion of correct sanitary conditions. The setting up of an educational campaign in the average city that is interested in sewage treatment is a very important and serious step in the development of a sewage treatment project. After all, we must remember that the voters control the outlet and destiny of engineering talent. Without the support of the public, there is no work to be done.

The city of Galesburg, Illinois, which organized a sanitary district under the State Law of 1917, is a typical case of how public opinion can be reversed on matters pertaining to public health when the citizens are actually aroused concerning the importance of the project. This community opposed the formation of the sanitary district by *quo warranto* proceedings, but the court upheld the district. Galesburg is a city with three newspapers, and prior to voting on their bond issue, an educational campaign was designed to make it possible for every individual to become acquainted with the real facts surrounding the sewage treatment project. The titles of a few of the editorials used in this campaign were as follows: "Civic Progress Dates from Installation of Modern Disposal Plant Methods;" "A Good Work Started;" "The Sanitary District;" "Real Sanitation;" "There Should Be No Delay;" "The Sanitary Bond Issue;" "Time's Up" and "Let the Bugs Do It."

The titles of several of the articles used in this campaign were as follows: "Will Vote on November 24 on Sanitary Bond Issue;" "Citizens to Boost $700,000 Bond Issue for Cedar Creek Improvement;" "Dream of Galesburg May Be Realized by Big Improvement of Cedar Fork;" "Sanitary District Trustees Give Facts;" "What the Construction Program of the Sanitary District Will Mean to You and Our City;" "'Know the Facts, Don't Guess,' say the Trustees;" "Trustees Tell of Construction Program of Sanitary District."

Addresses were also scheduled to be given before the Chamber of Commerce, five luncheon clubs, the Izaak Walton League and the Civic Department of the Woman's Club. These addresses covered a period of

eight days and the articles in the newspapers covered a period of twelve days.

It goes without saying that the newspaper editors of this community were solidly back of this program. The people of this community supported the bond issue and last spring the Galesburg Sewage Treatment Works were officially dedicated, with the newspaper editors taking a very prominent part on the program of dedication, ready and willing to sell continuously the importance of sewage treatment as related to public health.

In the Illinois *Health Messenger*, October, 1933, a report on the recently completed extensive stream pollution survey of 700 miles of stream in Cook County made by the State Sanitary Engineer and his associates states with regard to the abatement of stream pollution: "By education, coöperation, persuasion and legal means, if necessary, prevent and prohibit."**** It is interesting to know that legal means come last and education and coöperation come first in this rather unique phraseology. Public education on sanitation is the method by which this problem can be solved. It is the only successful way and it is a challenge to each one of us who is interested in the extension of correct sanitary service in his community.

The Newspapers.—The supplying of newspaper editors with a symposium on the subject of sewage treatment should be a nation-wide program. If editors were supplied with such material, carrying the approval of a national group of representative men trained in the science of sewage treatment, it would be of distinct service to a paper in preparing the public to accept sewage treatment as a community necessity.

My acquaintanceship with newspaper editors justifies, I believe, the statement that they as a group are always ready and willing to receive clear and non-technical information about projects that affect public health. The newspapers of the country could, and I believe would, if they had the proper material for publication, do much to encourage the building of sewage treatment projects. Newspapers have never shirked their responsibility when it comes to matters of public health. We must admit that in every city, town or village where sewage is being treated, a search in the files of the community newspaper will show that the newspaper editor was right out in front doing what he could to encourage his fellow townsmen to take advantage of this relatively new science. In selling sewage treatment, may I remind you engineers never to forget the importance of establishing an acquaintanceship with the newspaper men in the community in which you are working. Give him your time, answer all questions, give him all the facts about the job, get him actually acquainted and interested in what you intend to do. By giving him the complete story, you will find a coöperative and helpful aid in your com-

munity relationship. If you are going to sell sewage treatment, the public wants to know what it will cost.

The Cost.—In William D. Hatfield's article "How Much Do Clean Streams Cost?" published in *Outdoor America* in September, 1929, he states that Alvord, Burdick and Howson, in a report to the War Department in 1925, during the Water Diversion Controversy, estimated that the construction cost for complete treatment at Atlanta, Baltimore, Columbus, Pittsburgh, Lexington, Lincoln, Urbana and Marion was $9.60 per capita for settling tanks and sprinkling filters, and from $7.00 to $14.00 per capita for aeration treatment with activated sludge as at Milwaukee and Houston.

In an article by Mr. Samuel A. Greeley of the firm of Pearse, Greeley and Hansen, entitled "Illinois Sanitary District Developments," *Transactions* of the American Society of Civil Engineers, Volume 91, December, 1927, pages 441–458, a table is given showing cost of sewage treatment plants, excluding interceptors, to be from $9.00 to $12.00 per capita. According to Mr. Greeley, this means $2.00 to $3.00 per capita per year as a maximum expense.

The operating costs of nine complete plants throughout the United States varies from eleven cents to fifty-five cents per capita per year; according to Hatfield—"the cost of from one to five rolls of cheap toilet paper." Analyzing these figures still further, it can be seen that the total yearly per capita cost over a 10-year period is $3.55; over a 20-year period, $1.77, as the maximum expense for this health protecting project. The yearly per capita cost for the Urbana and Champaign Sewage Treatment Works for the past eight years was as follows:

	1925–26	1926–27	1927–28	1928–29	1929–30	1930–31	1931–32	1932–33
Operation	$0.43	$0.48	$0.35	$0.39	$0.41	$0.37	$0.36	$0.31
Interest and Bond Ret.	1.32	1.14	1.19	1.14	1.19	1.10	1.18	1.42
Total	$1.75	$1.62	$1.54	$1.53	$1.60	$1.47	$1.54	$1.73

To sell sewage treatment let the taxpayers know that treating sewage in a modern sewage treatment plant is actually cheaper than the correct maintenance of the residential cesspool. The cost of removing sludge from a residential cesspool is established around $3.00 per barrel among the men who do this type of work. I have been informed that a five-barrel removal is about the usual amount taken from a residential tank every two years. This means a yearly cost of $7.50 for the maintenance of the old-fashioned, unsanitary and health-endangering cesspool in condensed population areas, which is about double the amount to the average family of the above figures for correct sewage treatment. Sewage treatment in a modern plant is the most economical and far-reaching investment that the public can make.

The Opportunity Is Here.—The State Advisory Board at Indianapolis, at a recent conference in Chicago, stated that the Indiana Board was making every effort to develop sewerage and sewage disposal for Indiana, and made the amazing statement that only 7.9 per cent of all the communities of Indiana have sewage disposal plants.

In Illinois it is reported that 44 cities and villages have applied to the Federal Government for assistance in financing sewage treatment projects. Twenty-two communities of the 44, representing a population of 119,773, give an estimated cost for their sewage treatment projects of $1,645,000. The above figures represent a per capita cost for the population as specified of $13.71. This estimate, however, is not based on the future population for which the plants are designed, but on the present population, which makes the per capita figures appear high.

This estimate is certainly sufficient evidence that there is work to be done. The people are becoming sewage treatment minded. Is this opportunity going to be lost? Can we as a group do anything to guarantee to posterity the adoption of sewage treatment in our various communities? Just where are these applications as to approval by the Government? How soon will work actually start? These certainly are serious questions. If we get anywhere in the relief of the unemployed, action and not delay is needed.

Conclusion

Never before in our history has there been so much importance placed on the collection and disposal of sewage as at the present time. The words "Sewage Treatment" are actually becoming a common phrase in our newspaper service of today. The opportunity for real community service in this very important health protecting agency is before us. The scientist, the engineer and the builder are all ready, the science of sewage treatment is well established. Guess work is eliminated through scientific research during the past half century, but what are we doing about it? Are we, as disciples for clean streams, health and happiness, accepting this opportunity for humanitarian service? Are we doing our best to coöperate with the federal agencies? Have we recognized the importance of an educational program so necessary to encourage our people to take advantage of this health promotion work? Are we actually trying to sell sewage treatment? Has any well thought out and well directed educational campaign been developed to assist the taxpayer in making up his mind as to the best course to follow when a question of sanitation comes up in his community? Have the consulting engineers and manufacturers of equipment associated with sewage treatment called a general conference, where a complete and comprehensive study can be made of the situation to take advantage of this unique situation? I hope so, for much good

will come to our people through the application of the science of sewage treatment to their community life. As John Ruskin puts it: "Therefore when we build, let us think that we build forever. Let it not be for the present delight, not for the present use alone, let it be for such work as our descendants will thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor and the wrought substance of them, 'See! this our fathers did for us.' "

Excessive Ground Water in a Sewer System and Its Effect on Sewage Plant Operation*

BY C. A. EMERSON, JR.

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The majority of sewage treatment works installed at the present time are for municipalities where some kind of a sewer system is in existence. The designing engineer of a treatment plant ordinarily has but little control over the infiltration of ground water into the sewer system since he must adapt his design to existing conditions.

Occasionally, however, in the case of separate sanitary sewers, excessive infiltration of ground water may be due to inadequate design or faulty construction of a few relatively short lines in low-lying sections, where the sewer is below the permanent ground water level, or it may be due to leakage through inverted siphons at stream crossings. In such cases repair of the lines or their replacement should be given careful thought as such improvements will accomplish a permanent reduction in volume of flow to the sewage treatment works. Oftentimes the excessive flow in sanitary sewers during storms is not caused by infiltration but by storm water reaching the sewers through improper connections such as a few scattered street inlets, installed to relieve local flooding where storm drains were not available; to connections of roof water leaders; to connection of floor drains in cellars periodically flooded, due to poor construction of floors or foundation walls; or to perforated manhole covers throughout the system which were installed under the impression they afforded a necessary and proper method for ventilating the sewers. Three of these serious infractions of good engineering practice in sanitary sewer construction, namely, street inlets, perforated manhole covers and cellar drain connections, can be readily located and eradicated. The effective disconnection of roof water leaders is, however, a tedious procedure requiring patience on the part of an inspector in locating and proving existence of the connections and firmness on the part of the responsible authority charged with their removal. Roof water connections interfere with the functioning of a sanitary sewer system to a greater degree than is generally appreciated. The volume of water reaching the sewer from each roof is considerable and of even greater significance is the fact that water on the roofs flows immediately to the down spouts and reaches the sewers at practically the same time from the entire district, resulting in a peak load which is often sufficient to surcharge the sewers and completely flood the treatment works.

Infiltration through house connections may also be a serious matter

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and here the engineer designing a sewage treatment plant has opportunity to be helpful, for house services are being added from time to time and existing services are frequently dug up in order to remove clogging due to root growths or grease cemented deposits. There have been numerous instances where street sewers constructed under contract were reasonably watertight but house service pipes installed by plumbers without rigid inspection showed excessive leakage. In one case, with which the writer is familiar, infiltration into house services was sufficient to flood the treatment works. In recent years increasing attention has been given to improving the class of workmanship on house services by requiring inspection before the line is covered and also by specifying special joint materials. In some places cast iron pipes with lead or sulphur compound joints have been adopted as a standard. The installation cost has been only slightly greater than for terra cotta or concrete pipe and there has been striking freedom from leakage and root growths.

Sewage Treatment Works for Combined Sewer Systems.—In the design of sewage treatment works to receive the flow from combined sewers, provision must be made not only for handling the excess flow during storms, but also for taking care of the greatly increased quantity of mineral and organic solids representing the wash from streets and the flushing out of deposits stranded on the sides and bottom of large sewers during low velocity periods since the preceding storm. As most bypasses for excess storm water are of the overflow type, a large per cent of those solids which have specific gravities greater than water are carried into the treatment works. The various types of mechanically cleaned grit chambers which have been developed in recent years undoubtedly are more effective in removing these mineral solids than the older type of channel grit chambers which generally were not cleaned until the storm had passed and frequently not in time to handle the grit from a closely following storm.

In this country there is no uniformity of procedure in dealing with storm water, but some recent designs show the influence of well standardized British practices with adaptation to our larger per capita sewage flows. In England, regulations of the Ministry of Health require that flows up to three times the ordinary dry weather flow be taken through the treatment plant and that special storm water tanks be provided for sedimentation of flows between three and six times dry weather flow. As per capita water consumption and sewage flow in the United States generally ranges from two to four or more times that in English cities the equivalent capacity of storm tanks to be provided here would range from two to perhaps four times the dry weather flow, which would not materially increase the total cost of the works. The liquid remaining in the tanks is pumped through the regular treatment works when flow conditions have returned

to normal following the storm. These storm tanks serve to reduce the pollution of the stream and guard against formation of sludge banks in the stream and objectionable appearing and foul-smelling deposits on the shore in the vicinity of overflows.

Sewage Treatment Works for Separate Sewer Systems.—In these cases excessive ground and storm water may limit the normal capacity of the works or may be detrimental only during storms, depending upon whether due to infiltration into sewers laid below permanent ground water elevation or caused by cellar drains, roof water connections, street inlets and other previously mentioned defects of the sewer system.

Excessive rates of flow at the treatment plant due to continuous high ground water infiltration are manifestly undesirable limiting factors for pumping equipment and pipe lines connecting the various units, as such flows limit the designed capacity of these structures for increasing sewage flows in the future. These excessive flows likewise increase velocities through sedimentation tanks, with corresponding decrease in efficiency. As the organic content of ground water is relatively low, the effect on biological processes is relatively slight other than in the activated-sludge process, where the results attained bear a relation to the period that the sewage is in contact with the activated sludge.

The sudden increases of flow due to storm discharges of roof and cellar drains, perforated manhole covers, etc., not only detrimentally limit the normal capacity of the plant, but may also seriously disturb biologic processes.

Recently developed equipment, capable of carrying considerable overloads, has been helpful in overcoming the effects of such sudden increases in flow. For example, mechanically cleaned settling tanks equipped for frequent or continuous removal of sludge are more effective than the old-fashioned single-story tanks where increased velocities of flow tended to stir up settled solids and carry them over the outlet weirs to the detriment of subsequent treatment processes. Sustained high storm flows lock sewage siphons dosing sprinkling filters so that discharge from the nozzles may be at maximum rate for several hours' duration. This continuous flushing tends to wash the film from the stones and interferes with nitrification. In the final settling basins the increased velocities of flow reduce settling efficiency, as in the primary settling tanks.

In the activated-sludge process the sudden change in velocity of flow through aeration and final settling tanks may cause serious disturbance in performance, with marked deterioration in quality of the effluent.

Unless the designing engineer has full knowledge of storm flow conditions and makes adequate provision in the design, the value of the plant is materially reduced. While the overload can be removed by installation of overflows, as is customary in treatment works for combined sewer sys-

tems, such overflows are often procedures of doubtful expediency, as the dilution of organic matter during storm flows in a separate sewer system is much less than in a combined system and diversion of this excess flow is more apt to cause an active nuisance or a menace to health. It is probable that one of the best procedures in such a case would be to install additional preliminary treatment capacity so that all of the sewage would receive at least minimum treatment before discharge into the stream.

Discussion

BY CHARLES F. MEBUS

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Mr. Emerson stresses particularly the necessity for the designer to consider all possible contingencies that may have a bearing on the design capacity. However, unless a design is conscientiously carried out, even careful designing will be useless. One might think that with all the care which engineers are expected to take in design and construction in these days, only one hundred per cent results would be obtained. But the contrary is true, so far as my observation goes.

Some years ago the manager of one of the largest surety companies said to me, "Please examine and report on a sewer contract which has been constructed by a contractor for whom we are sureties. The work has been condemned by the city engineer and we are expected to make good the defects." I made the examination requested, and found that the plans and specifications called for a vitrified pipe sewer encased in a concrete cradle and, as it was laid partly in filled material, two heavy reinforcing bars were to be imbedded in the bottom of the concrete slab. The examination showed that the bars were omitted, a thin slab of inferior concrete was spread in the bottom of the trench, the pipe laid on top, joints not cemented, earth fill brought up to the top of the pipe and another thin layer of concrete spread on top.

I told the attorney of the surety company that I felt the city was entitled to receive whatever the bond called for as penalties. This advice was not kindly received and my services were no longer required, so I do not know the final outcome.

A few years ago, and again this year, my office was requested to make an inspection of the sewer system of a large housing operation. Before the operation was started surface drainage was taken by an open channel which runs across a cemetery adjoining the housing project. Last year, 1932, the cemetery superintendent was annoyed by foul odors arising from the creek channel and asked me to make an investigation and report. This was done, and it was discovered that the building operator had laid two

parallel sewers; one for house sewage, connected with the city sewers, and one for surface water which discharged into the open creek channel. Numerous tests were made which showed conclusively that the house connections to the two sewers were indiscriminately made. Some of the house plumbing was connected to the storm sewers and some of the surface water was discharged to the house (sanitary) sewers. The sewage in the open channel caused the odors.

In 1931, sewers and a sewage treatment plant were constructed under my supervision and in accordance with my plans for Upper Moreland Township in Willow Grove, Montgomery County, Pennsylvania.

The sewage plant is a joint undertaking and takes the sewage of the adjoining borough on the north. The level of the ground water is quite high and there is plenty of water. The Upper Moreland Township sewers were held within the limits for ground water infiltration specified—3000 gallons per mile in 24 hours. The borough sewers were laid under the supervision of the borough engineer who had no experience laying sewers in wet ground.

The agreement between the municipalities was that the cost of operating the plant should be borne in proportion to the quantity of sewage treated for each, so it was necessary to provide flow meters near the end of each outfall sewer before the sewage discharged into the collecting well. Simplex meters were used. The length of the township sewer is 5.5 miles and the borough sewer is about the same. The number of house connections in July, 1933, was practically the same, 260 for each. The township inspector for making house connections is intelligent and conscientious and gets good work done by plumbers.

For the first seven months of 1933, weekly charts show flows for the township sewer varying from 242,000 gallons to 607,000 gallons weekly. The higher figure was reached but once this year. The average daily flow was 49,645 gallons. The flow from the borough sewer was as high as 4,300,000 gallons in one week in March, and rarely registers below 600,000 gallons weekly. The average daily flow for the period was 218,091 gallons. Much money has been spent by the borough in an attempt to repair the leaks, but with rather meager success.

The worst example that I can recall is the sewer system of the Borough of Quakertown, Bucks County, Pennsylvania. Sewers and a treatment plant were constructed in 1926. The leakage in times of wet weather is all the system can carry—in fact there is one manhole at the lowest point in the borough which overflows every time there is a heavy rain. The water raises the iron manhole cover and the sewage flows out into a nearby stream. The topography of Quakertown is quite flat. Grades of the sewer are as low as one foot per thousand. There is much trouble from odors due to decomposed sewage solids which are held in the pipes

when the sewage is backed up. Manholes and interiors of the pipe are filthy, and sewage backs up for a distance of 1.5 miles from the sewage pumping station.

The construction is very faulty, both as to lines and grades, and foul sewage water is standing in the pipes. There are 11.6 miles of pipe with diameter of 15 to 8 inches.

The following list gives some of the defects:

In the early part of this year, an inspection of the entire system was made by means of sunlight deflected with mirrors through the pipes. It was found there were 440 visible leaks. There are 252 individual lines between manholes. Of this number it is possible to see through 111; that is to say, the percentage of visibility is 44. Bad odors arose from 155 manholes. There were deposits of sewage solids in 107 manholes. There are 289 places where there are visible bends in the line, and 128 places where the pipe is low.

To get a better idea of the quality of the workmanship and character of construction it was decided to open the sewers at twelve places in the fall of 1932. It was found that the 15-inch lines were broken in a number of places. That is to say, there is a crack on top of the pipe for its whole length. Some places were open as much as one-half inch. Connections to laterals in deep cuts were found to be sheared off and some riser pipes were merely stuck in through the top of the 15-inch pipe by cutting a hole through the pipe. In other words, "Y's" and eighth-bend connections were not used, nor was the riser pipe concreted as it should have been. In rock cuts it was found that the pipe was supported and brought to grade by wooden blocks or small stones. This support was insufficient, causing the pipe to move from the weight of the backfilling, and the joints to open, as well as some of the pipes to crack.

The borough is now engaged in reconstructing the lines which work will cost more than the original construction. Recently, during reconstruction, a straight trench was cut between two manholes; when the grade depth was reached, the pipe was found to be as much as two feet to one side. Asphalt jointing material was used, which for some reason did not adhere to the bells of the pipe and can be pulled out by hand in one piece. An attempt was made to protect the asphalt joints with cement mortar, but this was carelessly done and usually was quite ineffective. Again, through rock cuts, large stones were thrown back upon the pipe and the pipe was not only broken but big holes were made.

Tight sewer work *can* be done, as will be seen by the following:

In 1932, Radnor Township constructed 7.5 miles of vitrified pipe sewers along the creek valleys, of which 4.6 miles were in wet ground, in which the leakage was 1500 gallons per mile in 24 hours. There was also constructed along and below the bed of Darby Creek, so that gravity connections could

be made from the opposite side, 3.3 miles of 30- and 24-inch concrete pipe sewers. The infiltration was about 1200 gallons per mile.

In the Borough of Jenkintown, 10.9 miles of sewers have been laid, 3.1 miles of which were in wet ground. In 1932 the entire flow of sewage, which is metered where it connects with the Cheltenham Township sewers, was approximately 60 gallons per person per 24 hours.

The character of the work in Upper Moreland Township has already been noted.

My experience in laying pipe sewers in the past thirty years has been that one cannot take chances with poor foundations or unstable materials in the bottom of the trench. The only sure way is to lay the pipe in concrete cradle or at least one-half cradle. Neither can one take any chances with laying pipe in deep trenches without protection against its being crushed by the weight of the backfilling. It is necessary to take infinite care in making joints and unless an inspector is intelligent, honest and painstaking, good results will not be obtained. Frequent tests must also be made as the work progresses by allowing the ground water to rise up over the completed work to see if tight work is being done.

It appears to me that, as a general thing, sewer work is not carefully done. I have come to this conclusion because every time I get a contractor from a distance it is necessary to teach him anew how to lay pipe.

It is my further belief that it is wasteful to try to keep old sewer systems that have been improperly constructed or which carry surface water. Attempts have been made at Lansdale and Souderton and other places to bypass the excess storm water flow from such sewers with only a moderate degree of success.

Discussion

BY FRANCIS S. FRIEL

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There is a definite relation between the operating efficiency of a sewage plant and the rate of flow through the plant. When the flow materially surpasses the designed capacity there is a corresponding decrease in plant efficiency.

I have knowledge of a system serving a population of 4500 people, with a normal dry weather flow of 300,000 gallons per day. During and following rainy periods, the rate of flow through the plant increases to 900,000 gallons per day. The only reason this flow is not greater is because the sewage is pumped and the rate of 900,000 gallons per day is the maximum capacity of the pumping equipment. There are no rain water conductors nor stormwater drains entering the sewage system. As a result of this ab-

normal flow the percentage of solids removed in the settling tanks is reduced. Likewise, the relative stability of the final plant effluent is reduced from 96 per cent to approximately 60 per cent; and at times, much lower. This reduced efficiency is the result of the increased velocities through the primary and secondary settling tanks and the increased rate of filtration of the sprinkling filter. Inasmuch as the sewage at this plant is pumped, operating expenses are likewise greatly increased.

In many cases, sewer systems have been poorly constructed. Ordinary rates of infiltration in a well built sewer system vary from 4000 to 40,000 gallons per day per mile of pipe. In some instances, rates as high as 240,000 to 1,000,000 gallons per day, per mile of pipe, have been found. Most authorities upon the subject fix a rate not to exceed 20,000 gallons. From my experience, however, I feel that this rate can be materially reduced.

On new sewer construction great care should be exercised to obtain tight lines. This may be accomplished by rigid specifications and inspection of construction. Regardless of the confidence you may have in a contractor, an experienced inspector should remain upon the work at all times when pipe is being laid or manholes constructed. A trench which is dry when a pipe line is installed, may later become wet, and if care is not taken with the joints, leaks will occur.

Then again, a sewer system may be properly constructed, but if precautions are not taken, the house connections may leak and thus ruin the good work accomplished on the construction of the sewers. Every municipality should enact a rigid code governing house connections and this work should receive the same expert inspection as the sewer lines.

It is the general custom to install vitrified clay pipe in a sanitary sewer system. The pipe should preferably be in three-foot lengths and the joints made of mortar composed of one part cement and one part fine sand. I prefer cement joints to the so-called tar joints. At times it is advisable to use quick setting cement. In a wet trench, vitrified pipe lines should be encased in concrete, either to the springing line of the pipe or completely around the pipe. Water should be pumped from the trench and not be permitted to rise over the pipe lines for a period of twenty-four hours after concrete is poured or joints constructed. It is desirable at times to use cast iron pipe, or centrifugally cast pipe, with lead joints, on main outfall sewers which are laid parallel with streams. This latter type of construction may prove cheaper than vitrified pipe encased in concrete, depending upon the cost of cast iron pipe.

Manhole construction must not be overlooked. In a wet trench, brick manholes should be plastered on both the inside and outside with not less than one-half inch of cement mortar. Frames and covers should be designed to exclude surface water during storms. Ventilated covers should only be used at summits and dead ends.

If the construction principals outlined above are followed, it is possible to install a sewerage system with a minimum quantity of leakage. In the Gully Run District of Lower Merion Township, Montgomery County, Pennsylvania, 5.2 miles of sewer lines, ranging in size from 8 to 15 inches, were constructed. For the most part the lines were installed in a wet trench and the measured leakage was at the rate of 1630 gallons per day per mile of pipe. At Bridgeport, Pa., for that portion of the sewer system laid in a wet trench, the rate of infiltration was 1200 gallons per day per mile of pipe. In both of these cases the sewage is pumped and tight sewer lines were essential.

Comparatively tight sewers can be constructed under adverse conditions if care is exercised. Specifications for new work should not permit over 5000 gallons of infiltration per mile of pipe. To accomplish this, however, constant supervision by an experienced inspector is required, also the proper realization of the construction problem by the designing engineer.

Operating Experiences in New York State*

BY CHARLES C. AGAR

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Supervision over sewerage and sewage treatment facilities in New York State is vested in the State Department of Health. The Department through the Division of Sanitation examines all plans for sewer systems and sewage treatment plants, and if approved by the Department a permit for the discharge of the sewage or sewage effluent is granted. This permit specifies the conditions under which it is operative and reserves the right to require more adequate and satisfactory disposal of the sewage whenever deemed necessary by the State Commissioner of Health. Plans for industrial waste treatment and discharge of waste effluents are likewise examined by the Department and permits granted upon approval.

The magnitude of the task of reviewing plans for sewers, sewer extensions, sewage treatment plants and industrial waste treatment plants can be appreciated by the fact that during the year 1932 a total of 248 plans for sewerage, sewage disposal and waste disposal, involving a cost of $6,500,000, were approved. Of this number, two were for municipal sewer systems and treatment works, 19 for sewage treatment plants, 10 for comprehensive sewer systems and 103 for municipal sewer extensions. The remainder were for private, institutional, school or industrial waste disposal facilities. This number and the estimated cost involved are somewhat less than during the past few years and are undoubtedly affected by the present general financial conditions.

There are in New York State some 363 sewer systems, serving a population of 10,528,000, or 83.5 per cent of the entire population of the state. One hundred and sixty-six municipalities provide for some degree of treatment of their sewage in a total of 190 sewage treatment plants, ranging from fine screening as the only treatment in some cases, to primary sedimentation, oxidation, secondary settling, sand filtration and chlorination as the treatment in a few instances. In addition, there are about 52 municipalities or districts served by plants owned by other cities, villages or districts. The total population served by municipal treatment plants is about 2,170,000 or 20.5 per cent of the population served by sewer systems.

Classification of the treatment plants as to type shows that there are 16 plants employing fine screens alone or in conjunction with chlorination, and 107 plants in which treatment consists of primary settling, with or without chlorination of the effluent. These plants may be divided into

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three groups, consisting of 44 plain sedimentation or septic tanks, 22 settling tanks with separate sludge digestion and 50 Imhoff tanks. Very few plain sedimentation or septic tanks have been approved for municipalities during the past few years, and present regulations of the Department discourage such installations.

The remaining 67 plants consist of various combinations of primary and secondary treatment processes. There are still 11 municipal plants in the state where contact beds are employed. Trickling filter installations predominate as secondary treatment units of which there are thirty-four. Sand filters are used at 17 plants. Six of the latter installations consist of natural sand percolation beds and are located principally on Long Island where soil conditions are favorable for such disposal.

There are three municipal activated-sludge plants operating in the state and one practically completed at New York City. It is interesting to note that two of these plants are located on Long Island, where the effluent is disposed of in natural sand percolation beds.

There are 22 separate sludge digestion plants, eleven being equipped for gas collection. Sludge gas is used for heating purposes. At the three activated-sludge plants the gas may be used for furnishing power for the plant and for operating the air compressors. Nearly all of the separate sludge digestion plants have been constructed during the past six years, and those equipped for gas collection and utilization, during the past four years. There has been a tendency for this type of plant to outnumber new installations of the Imhoff type, although the Imhoff type of plant will continue to hold its own for some time as a primary treatment process. Final or secondary settling tanks following secondary treatment processes are used at 25 plants. The present regulations of the Department require the installation of such units where trickling filters are installed.

Chlorinator installations number 88, and 20 of these are arranged for prechlorination. Chlorination during the summer season only is carried out at 44 plants for the purpose of protecting bathing beaches, reducing the oxygen demand on streams, inhibiting decomposition until adequate dilution is obtained, or for odor control. The remainder are operated throughout the year. The increase in the use of chlorine during the last few years has been one of the outstanding examples of the adaptation of a simple and relatively inexpensive process for disinfection, together with many other incidental advantages in improving treatment efficiency.

In regard to sludge drying beds, 83 plants employ open air beds, and 30 plants make use of glass enclosed units. The increased use of glass enclosures during the past ten years has been pronounced, and operating results at many plants to date appear to justify their use, where rapid drying, limited areas, protection from inclement weather, and, in some cases, odor control are factors for consideration in designing a plant.

In addition to the municipal plants, there are many institutional and private plants concerning which complete information is not readily available. Some of the larger institutional plants, particularly at state institutions, rival municipal plants in magnitude and number of operating units.

During the past four years fifteen new sewage treatment plants have been constructed at various state institutions in New York State. Plans are now being prepared for four more. The state thereby is setting an example for municipalities in preventing undue pollution of the watercourses of the state. All of these institutional plants have been planned on a liberal design basis and make use of modern developments in the sewage treatment field. Imhoff tanks and trickling filters predominate, with separate digestion and activated-sludge plants among those more recently designed. Glass enclosures for the settling tanks and sludge beds are used where practical, and at Great Meadow prison the trickling filters with revolving distributors are also glass covered. At Napanoch a similar installation is open. One of the largest institutional treatment plants is at Harlem Valley State Hospital and is now nearing completion. This plant will employ the activated-sludge process with mechanical aeration. At the Hudson River State Hospital at Poughkeepsie, the mechanically cleaned settling tanks are glass enclosed and the sludge is treated in a separate digestion tank and disposed of on drying beds (glass-covered).

The operating problems at institutional plants, particularly at the older ones, are more acute and of a different nature than at municipal plants. Extreme variations in sewage flow, excessive amounts of grease and scum, unusual volume and character of screenings, and laundry wastes all contribute to operating problems at such plants.

As an aid for officials and operators in charge of sewage treatment plants, our Department has prepared a bulletin entitled "Operation and Control of Sewage Treatment Plants." This bulletin furnishes information concerning operating details in clear, concise language which the layman or plant operator can readily understand. A recent reprint of this bulletin not only contains detailed information regarding the care of the various units of a plant, but also includes a description of many laboratory tests commonly used at a treatment plant to determine the efficiency of the plant or to regulate its operation.

The laboratory methods recommended show some deviation from generally accepted practice. For example, the settleable solid test is carried out in a one-hour basis rather than two hours. More consistent results and results showing a closer relation to plant operating conditions are indicated by the one-hour settling data.

Monthly report forms are provided by the Department so that a daily record of plant operation may be kept. These reports are transmitted to

the Department at the end of each month and acknowledged with appropriate comments. The Department has been very successful in obtaining reports upon the operation of many plants in the state. In 1929, 10 reports upon the operation of sewage chlorination plants were being received. Since adopting forms which give information concerning the operation of various units of a plant in 1930, the number of reports has been increased by field activity and follow-up work so that today reports upon the operation of 99 plants in the state are being received regularly. Such reports, properly kept, provide a ready means of obtaining a picture of plant operating conditions. They show the attention that the plant receives and some indication of operating efficiency. Their value as records in case of law suits is inestimable. When modifications or enlargements of the plant are necessary the information is valuable in planning such changes.

These report forms consist of two principal types, each applicable to a certain type of plant and degree of treatment. The first form provides for information concerning the operation of primary treatment processes, either with or without chlorination. Provision is made for recording information regarding weather conditions, sewage flow, screenings, routine care of tanks, sludge depth, pH value, and temperature, settleable solid tests, chlorination data including daily weights of tanks and residuals maintained, sludge bed operation with quantities of sludge handled, monthly cost data, condition of the outlet watercourse, and general notes on plant operation.

The second form provides for the same type of information regarding the primary treatment processes and also data on separate sludge digestion, trickling filters, sand filters, secondary settling tanks, etc. Provision is also made for recording the results of some of the usual laboratory tests, such as suspended solids, total and volatile sludge solids, nitrates, dissolved oxygen, B. O. D. and presumptive *B. coli*.

A third type of form is that used for special plants such as activated-sludge plants, or municipalities desiring report forms on a weekly rather than a monthly basis. A few of these miscellaneous forms are in use but the great majority of reports are on the forms furnished by the Department.

Short schools for sewage works operators were held at Union College in 1931 and at Cornell University in 1932. Plans are well underway to hold a third school at Cornell during the spring of 1934. The first two schools were intended primarily for elementary students, although many with considerable experience profited by the varied courses given. The 1934 school will provide courses for both elementary and advanced students.

There have been many definite results from the schools to date. The men have acquired an understanding of the meaning of sewage and of sewage treatment; the purpose of treatment, treatment devices and their

care and operation, and simple laboratory control tests. They develop a common language and are able to talk "shop" with understanding. They bring back to their respective municipalities new ideas and an added sense of responsibility whereby they can appreciate the importance and public health significance of sewage treatment.

Improvement in the condition and operation of the plants has been one of the very definite results of the short schools. Reports upon plant operation have been started and many new plant control laboratories installed.

The ensuing discussion includes a few of the usual and unusual, not to say at times humorous, conditions found during inspections.

Bar Screens.—At a few plants it has been found that the operators considered the bar screen a nuisance and an unnecessary impediment in the path of the sewage flow. Some operators have found that less daily attention was necessary if the bar screen were removed. One of the operators stated that he had to rake the screen every day or oftener to prevent back-flooding of the outfall sewer, so he removed the "darned thing" so he wouldn't have to visit the plant so often. Needless to say, the value and use of the screen was brought home to him when he drew sludge from the tank and had to spend several days in removing rags and debris from the sludge lines. A few operators also conceived original methods of screenings disposal. One operator turned a fire hose on the screen so as to wash the screenings through. Another found that screenings disposal was simplified by pulling the screenings over the screen into the tank inlet channel. I was sorry to find that no sludge drawing problems were experienced, but after explaining the purpose of the screens to prevent clogging of pumps and sludge lines, the practice was discontinued. The usual practice is to rake the screen at least daily and to bury the screenings.

Plain Sedimentation Tanks.—There are still a large number of plain sedimentation or septic tanks in use at municipal treatment plants. These are invariably covered, either by a concrete or wooden roof or by a house structure. Such tanks usually yield an effluent of inferior quality compared with that of Imhoff or mechanically cleaned settling tanks. In addition to a poorer quality of effluent, sludge disposal and odors are the chief problems. The odor problem in a few instances has been controlled by prechlorination while the sludge odor and disposal problem has been aided materially by a liberal use of chemicals such as lime and chloride of lime.

While mentioning that all septic tanks are usually covered, it is interesting to note the trend in modern housing at treatment plants. We find glass enclosures for tanks and trickling filters as well as for sludge drying beds. Imhoff tank housing was fairly common at plants installed 10 to 15 years ago. Unfortunately many of those structures did not permit ready

use of the necessary control implements. Where low roofs or covers were constructed, we have succeeded in having these removed or adequate openings provided in the majority of instances. One of the most unique housings found is that for an Imhoff tank at Wappinger Falls. The structure resembles an Indian tepee about 40 feet high with ventilation at the top.

Some of the experiences in the operation of treatment plants almost entitle them to a space in Ripley's "Believe It or Not" column. At one plant the operator attributed his success in the operation of plain sedimentation septic tanks to the presence of brewers' yeast and wastes in the sewage. This, mind you, during the days of prohibition. He then developed the practice of collecting the waste brewers' yeast and periodically inoculating the septic tanks to maintain digestion. With the return of legal beer the source of this material has been cut off so that now he is endeavoring to make arrangements with breweries in a nearby city to secure a regular supply of the desired inoculum. Who can complain about the detrimental effects of the home brewing industry in the sewage treatment plant when we have this example of beneficial effects?

Imhoff Tanks.—Imhoff tank installations provide many interesting operating problems. Perhaps the most common are those relating to "foaming" troubles and excessive scum formations. It has been found that a large number of plants have experienced "foaming" difficulties at some time. Most of this trouble has occurred during the initial stages of digestion when a new tank was placed in operation, whereas at others it has followed large sludge withdrawals from the tank. Trouble from foaming has also resulted from the presence of cannery, milk or other acid-producing wastes in the sewage. Another factor which has entered into some foaming troubles has been the summer rise in the temperature of the digestion compartment after the winter accumulation of solids in the tank at temperatures in some cases as low as 42° F. There have been a few cases of foaming for which no definite explanation is assigned. Corrections or control in most cases has been a matter of time and daily attention by the plant operator. Hosing, water jets, puddling, squeegeeing, etc., have all been tried with more or less success.

Experience has shown that hydrated lime added at daily intervals to the gas vents of the tank will aid materially in correcting a foaming condition and also provide many other desirable control features. When added at a rate of about 10 pounds per 1000 population per day, foaming difficulties have disappeared within a few days to a week or two and scum reduction, odor control and pH improvement of the sludge have also resulted. Addition in solution form has been tried at a number of plants, but this method is cumbersome and difficult to carry out. The general practice is to sprinkle the lime over the scum in the gas vents, allow it to become moistened and dissolved somewhat in the scum layer, and then thoroughly break up the

scum, which should not be over 12 to 18 inches in depth. If thicker than this it is removed before starting the treatment.

As indicated above, the excessive scum problem has been corrected at many plants by frequent use of lime and subsequent agitation of the scum layer. I am not prepared to say whether the lime or the agitation is the controlling factor, but definite improvement at many plants has resulted from this procedure.

A large number of plants having excessive scum formation in the gas vents of Imhoff tanks have been found at institutions, and such conditions of upside down tanks seem to be correlated to the presence of large volumes of laundry wastes. At one institutional plant in the western part of the state, at Perrysburg, the scum problem was promptly solved when a separate treatment plant was installed for the laundry wastes.

Scum on the sedimentation compartment is usually removed daily and placed in the gas vents of the tank. At East Syracuse, where unusual conditions exist during the summer season, the scum formation has been difficult to control and no ordinary skimming device would remove the finely divided greasy material. A small amount of hydrated lime sprinkled over the scum effectively controlled the odors from the material and tended to coagulate the scum so that it could be removed with the skimming device.

A simple and effective scum collecting device is used at the Glen Cove plant. A fine mesh screen extending across the width of the tanks is supported on wires running the length of the tank. When the scum is to be removed the screen is pulled the length of the tank, bringing all scum to one end where it is removed and placed in the gas vents. The gas vents at this plant, incidentally, are covered with concrete slabs, so that the scum is always submerged. Water pressure or hosing is used at most plants to settle the scum on the sedimentation compartment or force it to the end of the tank, where it can be removed readily.

Imhoff tanks are provided as final settling tanks at two plants in the state. Experiences at these plants have indicated that an ordinary gas vent area of 20 per cent is insufficient to accommodate the quantity of scum produced. At one of these plants, at an institution, the gas vent is filled with gas lifted snail shells originating in the trickling filter underdrainage system. It is reported that stirring up these shells causes a rattle similar to dry peas in a pod, or maybe the Mexican jumping bean. (I can't vouch for the truth of this statement as the shells have been either wet or full of rain water when I visited the plant.)

Separate Digestion Plants.—Separate digestion tanks, when heated, are maintained at a temperature of about 80° F. Daily sludge removal from the settling tanks is desirable, and mechanical equipment for such tanks has very definite advantages over hopper-bottomed tanks, both

in positive removal of the sludge and in removal of the floating solids.

Half of the 22 separate digestion plants are provided with heating facilities, and almost invariably these consist of gas-fired hot water boilers with coils in the tanks and a recirculating hot water pump. Corrosion of the boilers and flue stacks has been noted at several plants. The presence of small amounts of hydrogen sulphide in the digestor gas, giving sulphur dioxide on burning, together with condensed moisture in the boiler and stack, is probably the cause of such corrosion. It is believed that some plants where hydrogen sulphide is present in the gas could profitably consider gas-scrubbing devices. The cost of such devices must, however, be weighed against the cost of replacements and depreciation. Operation of the hot water boiler at higher temperatures and passing only part of the recirculating water through the boiler, the remainder bypassed to mix with the heated water, appears to have definite value in maintaining higher temperatures in the flues and preventing condensation.

At East Rochester the digestion tank is a two-story structure, or modified Imhoff tank, the top compartment being for sedimentation, equipped with mechanical sludge removal equipment, and the bottom for sludge digestion equipped with mechanical stirring. Gas collectors are placed around the top of the circular tank. This gas is burned in a boiler producing steam which heats, by a heat exchanger, the recirculated supernatant liquor in the digestion compartment.

Excessive scum problems and foaming have occurred at a number of plants, but have usually been corrected by recirculation and the use of lime.

Two digestion units, though costing slightly more than a single unit, are preferred because of the greater flexibility in operation.

Overflow liquor is usually returned to the plant influent at a slow rate so as to prevent an abnormal organic load on the plant from this highly organic material.

Gas holders are desirable auxiliary units for gas utilization.

Unheated tank temperatures, where the tanks are unprotected, have dropped as low as 37° F. at Huntington during the winter, and temperatures of 42° to 45° F. are common, showing that practically no digestion is accomplished during the winter months.

The physiological and physical effects of sewage gas have been reviewed in an article by the writer appearing in *Waterworks and Sewerage* for March, 1933. This article also points out the necessity of observing proper precautions and of using protective devices where such gas may be present.

Trickling Filters.—Trickling filter installations have developed their share of problems, from clogging to flies and odors. Very little filter clogging is experienced during the summer season, and clogging is usually

confined to a period of two to three months during the middle and late winter season. In a few instances clogging has been the result of ineffective preliminary treatment resulting in the discharge of sewage solids onto the bed. In many instances, however, clogging is one of those things that just happens. During the winter season control measures have usually consisted of manual work on the bed by picking or punching holes at frequent intervals through the top layer of stone. Resting the bed is also helpful if it is possible to cut out sections of the filter area. Chlorination with chlorine gas or chlorinated lime in the few instances it has been tried has also been very effective in correcting pooled beds.

Nozzle clogging is common and requires daily attention at the majority of plants. No freezing of nozzles or risers is known where the nozzles have been kept clean and the sewage flow maintained. The use of $^1/_4$-inch to $^1/_2$-inch mesh screens at the outlet of the primary settling tanks has greatly reduced nozzle clogging. It has also been found that there is much less ice formation on a bed in the winter when nozzles of the flat-spray type are used, indicating a greater distribution of the sewage with this type nozzle.

The dangers from freezing of distributors during the winter season has been minimized in many instances by the installation of bleeder valves on the distributing system, or by slightly opening a filter bypass valve on the system. Some of the operators have gone a step further in preventive measures and have removed the nozzles completely from the bed, thereby transforming the bed into a number of gushing fountains which, to say the least, is not conducive to effective oxidation of the sewage.

Pre-chlorination at low rates of dosage has been found to be the most practical procedure for odor control.

Sand Filters.—Sand filter operation in New York State follows the generally accepted practice, with periodic dosing, resting and hand cleaning. Several of the sand filters are located on Long Island where the naturally sandy deposits make it possible to dispose of the effluent by natural beds without underdrainage systems. At some of these latter installations, equipment such as tractors and harrows are used in the care of the beds, after first removing all deposited organic solids. The use of such heavy equipment on underdrained beds is not recommended because of possible damage to the drainage system.

At some sand filter installations in the northern part of the state, ridges or piles of the top surface of the bed are prepared so as to hold ice off of the main body of sand, especially where filtration is slow during the winter season.

Distribution of the sewage on the beds is either from the sides or corners or, in a few instances, by means of troughs carried out onto the beds. At the Pilgrim State Hospital, on Long Island, distribution is secured by a

large pipe from the dosing chamber extending to the center of each bed, with the bed in the immediate vicinity of the outlet protected by stone blocks.

Perhaps the most unique method of distribution is at Briarcliff Manor, and consists of the use of subsurface laterals with trickling filter nozzles spaced at 25-foot intervals over the beds. A 3-foot concrete slab surrounds each nozzle, and the discharge head is provided by intermittent operation of a pump through a force main about one-half mile long to the filter bed site.

One ingenious operator found a positive method to eliminate pooling on a sand filter. I hesitate to mention it for fear it may give ideas to some of the operators who may be prone to try anything suggested. The method consisted of punching holes down through the bed to the underdrains with a bar. Needless to say, this practice was soon discontinued.

At one of the sand filter installations, which has been in use for several years, continual difficulty with pooled beds was experienced. Investigation of the underdrainage system showed that the tile had been laid without open joints or gravel so that the tile lines were practically tight.

Sludge Removal.—At Penn Yan, the sewage treatment plant consists of a housed septic tank followed by contact beds for secondary treatment. At the time of my first inspection, it was found that the means of removing the sludge from the tank was one of the most unique ever seen. A hole had been cut through the roof of the tank and one end of an endless chain slat conveyor, similar to that used at a cider mill, was resting on the bottom of the tank and the other end elevated, so that the sludge could be moved up the chute, falling into a trough leading to a sludge lagoon. Needless to say, odor complaints when sludge was being removed were common, and it usually took about a week to clean the tank, the plant being bypassed in the meantime.

Another unusual type of sludge pumping was that employed at Oriskany to remove sludge from a sump, to which the sludge was drawn from an Imhoff tank by gravity. Above this well there was an endless chain bucket type of water pump common on farm wells. The handle of the pump had been removed and a pulley, belt connected to a gasoline engine, substituted. The operator stated that if nothing happened out of the ordinary, he could pump out all the sludge in a week.

In both of these cases modern sludge pumps have been installed and sludge pumping is now a matter of a few hours instead of days.

One of the greatest fallacies which we have had to combat in regard to drawing sludge has been with respect to sludge removal from Imhoff tanks. It seemed to be common practice to empty the tank of all sludge, or in other words, "drain her," "let her run until clear," "flush her out," etc. By explaining the value of "seed" sludge left in the tank and the

improved drying of sludge on a bed, when well digested and drawn in small amounts at frequent intervals rather than large amounts infrequently, this practice has in large measure been corrected.

The majority of plants are arranged for gravity withdrawal of sludge to the sludge drying beds. When pumping is necessary, conventional type sludge pumps of the centrifugal, plunger or diaphragm type are used. The plunger or diaphragm type appears to be best suited for removal of digested sludge, inasmuch as the rate of withdrawal can be more readily regulated and kept at the desired minimum.

At the Hamilton plant, sludge is removed from the plain settling tank by means of a vacuum pump and tank, and then discharged by gravity to the separate digestion tank.

Sludge Beds.—In the operation of sludge drying beds, the most interesting incident consisted of the use of a glass covered sludge drying bed as a tomato greenhouse. The operator withdrew about 1 to 2 inches of sludge on the bed and after a short time he noted a prolific crop of tomato plants. It seemed a shame to fork them out so the operator let them grow and invested in a crate of berry baskets in which to market the tomato plants and later the ripe tomatoes. I arrived at the plant during the winter after it had been in operation about a year and found the remains of a thriving tomato business. No further sludge had been removed from the Imhoff tank and the sludge elevation in the tank was well above the slots.

The disposal of the sludge solids from a treatment plant, though not the primary consideration in the treatment of the sewage, usually is the cause of a great amount of labor. It is this labor that causes the plant operator to view the sludge disposal problem with concern. When the sludge is ready to remove from the tank, it is usually dried on a sand bed equipped with underdrains. After a period of drying it is removed with a fork and transported to a storage pile or to the ultimate point of disposal.

At many plants in the state, the sludge is sold or utilized by the municipalities for fertilizer purposes. The cities of Schenectady and Rochester dispose of their entire output in this way and there are a large number of smaller municipalities which are following a similar practice.

A recent installation of vacuum filters at the Rockville Center activated-sludge plant makes possible the filtration and subsequent incineration of the sludge as well as the filtering of raw sewage and effluent to remove the suspended solids.

Glass enclosures for sludge beds offer definite advantages for sludge drying facilities, particularly during the winter season. We allow a 50 per cent reduction in drying area if glass enclosed beds are used. The full benefits of such enclosed units are, however, frequently lost by high side walls, or inadequate ventilation. In general the beds should extend north

and south, have inswinging lower sash, and side walls not over 18" above the sand surface.

It has been found that odor nuisances from poor sludge cannot be entirely controlled by a glass enclosure. Closing the ventilators causes excessive sweating without material drying of the sludge. Experiences in the treatment of sludge with chemicals to facilitate drying was covered in the writer's paper on the subject appearing in THIS JOURNAL for March, 1933. Chemicals such as lime, chloride of lime, alum, ferric chloride and chlorinated copperas have been found to have definite value in facilitating sludge disposal.

Industrial Wastes.—The problems arising as a result of industrial wastes have been many and varied, and I can indicate only in a general way the nature of each. Milk wastes have caused most of the waste problems. The effect of such wastes, particularly those containing skim milk or whey, have necessitated their elimination from the sanitary sewer system. Odors, overloaded tanks, clogged filters and foul conditions in the effluent watercourse have developed where mixed milk wastes have been discharged in quantity into the sewer system. Under ordinary conditions, that is, where the industry is not disproportionately large in relation to the village population, wash and rinse water may be admitted to the system without serious effect on the plant. It is difficult, however, to control the type of material discharged into a handy sewer, so we attempt to discourage the practice as much as possible and encourage separate treatment or disposal of all milk wastes.

Cannery wastes probably are next in order of frequency as the cause of problems. Such wastes have in some instances completely upset the operation of a plant so that even a fair quality of plant effluent could not be obtained. If Imhoff tanks were involved, acid sludge, excessive scum formations, obnoxious odors and inferior effluent have been common. Preliminary treatment of the cannery wastes by fine screens has reduced somewhat the operating problems at some plants but many are able to function only because of the shortness of the canning season so that recovery is attained before the winter season. The Department has carried out extensive investigations of the canning waste treatment problem in coöperation with the canning industry, and has prepared a bulletin on "Treatment of Canning Wastes."

Tanneries, though not numerous in New York State, have been the primary cause of serious treatment problems at two plants in the state. In one instance, the trickling filter became completely clogged with the wastes. A program of preliminary treatment at the tanneries and subsequently a change in processes, together with the business depression, enabled the filter to recover somewhat after much manual work in moving and washing the top stone. In the second instance, the contact beds pro-

vided for secondary treatment have been completely clogged with the tannery waste materials so that it will be necessary to provide a different type of secondary treatment unit.

Experimental Work.—Considerable experimental work has been carried out at some plants in the state. The use of ferric chloride as a precipitant at the Freeport plant, which has plain settling tanks with separate digestion, showed an improved quality of effluent possible with its use.

At Saranac Lake and at Rome the utilization of heat from the waste gas burner to supply hot air inside the floating covers of the digestion tank has shown definite improvement in sludge digestion and gas production.

Experiments with chlorination and recirculation of primary tank sludge at Newark have shown possibilities of modified treatment practice. At this plant the disposal of excess activated and raw sludge by a vacuum filter was greatly improved by chlorination of the material.

Ferric chloride as a sludge coagulant has been tried at many plants with generally good results, but without economical value where present sludge drying facilities are adequate.

Conclusion.—In conclusion, I wish to point out the increasing consciousness of the public to sewage treatment, the desire to prevent further pollution of our natural watercourses, and to restore polluted streams to within the limits of purity necessary to prevent nuisance conditions or menace to health, and to sustain normal fish and aquatic life. We will be doing our part if we continue to acquaint the public with our aims and purposes. Have them visit the treatment plant! Explain the operation of the plant; appear before service club organizations; and, I might add, make your local newspaper man familiar with your problems. It is only through continual effort and painstaking work that the greatest good can be accomplished. It has been found that the great majority of plant operators mean to do the right thing but are often at a loss to know exactly what to do. Common sense and practical adaptation to a sewage problem are virtues to be encouraged and the plant operator will find that the state engineers familiar with sewage treatment problems will be sympathetic and able in many cases to materially assist a willing operator. The old idea of a state inspector visiting only to find fault is passing, and we have the dawn of a new era when operating problems are approached with due respect to the capacities of the treatment plant and the demands of the situation. If changes in operation are desirable or necessary, it is not enough to say, "Do this or do that," but the reason for the change must be explained. In this way, and only in this way, will we be able to maintain friendly and coöperative relations between the state and the municipality to the end that efficient and effective treatment of the sewage wastes will be maintained at all times.

Discussion

Mr. H. M. Freeburn, Philadelphia.—There is one point I would like to stress and that is that you can't always go by what is written in text books on sewage treatment. Take two sewage treatment plants identical in design, in different places, and they will have different problems. The thing to do is to use good common sense and good judgment and find out what the trouble is.

With reference to state institutions' sewage treatment works, I believe that the states should set an example to municipalities. State plants should lead the way and even provide treatment plant facilities in excess of what are required.

In regard to punching holes in a trickling filter—it is poor policy and poor business.

Concerning the scum on sedimentation compartments of tanks, I think the scum frequently gives trouble because it is finely divided and, in getting it off, the scum is broken up and passes over to the secondary units. But if you allow it to remain another day and get a thicker layer, you have a better opportunity to skim it off. One advantageous method of removing scum is by means of a slotted horizontal pipe or trough, with the lip of the slot lying at the surface of the sewage. By rotating the pipe or slightly raising the flow line the scum can be drawn off the surface and discharged to grease traps, to a sump pump or elsewhere as desired.

Sewage Collection and Disposal at Lancaster, Pennsylvania*

BY J. F. LABOON

With the J. N. Chester Engineers, Pittsburgh, Pa.

When the present Mayor and City Commissioners of the City of Lancaster took office January 1, 1930, they were committed to a program of public improvements involving the sewer and water departments and, therefore, employed consulting engineers in the fall of 1930 to make a complete and comprehensive survey and report on the sewerage system and water department facilities. The area of the City of Lancaster has remained constant at four square miles, being two miles square, for almost 200 years, in spite of the efforts, at times, of outlying communities to annex themselves to the city. The survey, however, was based on a comprehensive scale, involving not only the city proper, but also the provision of sewerage and water facilities for areas outside the city where large communities have been built up, and a number of large industries established. Surveys were made to place the entire sewerage system on a common datum basis and to develop the grades of the existing sewers in order that their capacity might be calculated. Every sewer in the City of Lancaster was so treated and its capacity determined. Continuous measurements of flow by means of weirs were made of the Clay Street, Water Street and Stevens Avenue outfall sewers, and composite samples of sewage were collected at the same time for analysis.

A sanitary stream survey was made of Conestoga Creek, into which the sewage of the city was discharged. This survey included a determination of the dissolved oxygen of the waters of the stream for a distance of 17 miles below the Clay Street outfall. This survey was made for the purpose of determining whether or not secondary treatment was necessary at the southern limits of the city, where the Water Street sewer discharged into the Conestoga Creek. It was interesting to find that, with the dissolved oxygen content of 9.2 p. p. m. in the creek waters above the Clay Street sewer, and with all of the sewage of the City discharging into the stream below this point, the stream 5.4 miles below the Water Street sewer had a dissolved oxygen content of 11.2 p. p. m. The fall of the stream is about two feet per mile, with a number of small rapids and dams.

The study and report developed the prospective sites for the sewage treatment works and sewage pumping stations, and also the type of treatment works and the number necessary to serve the city most economically.

The total expenditure recommended by the consulting engineers, as a

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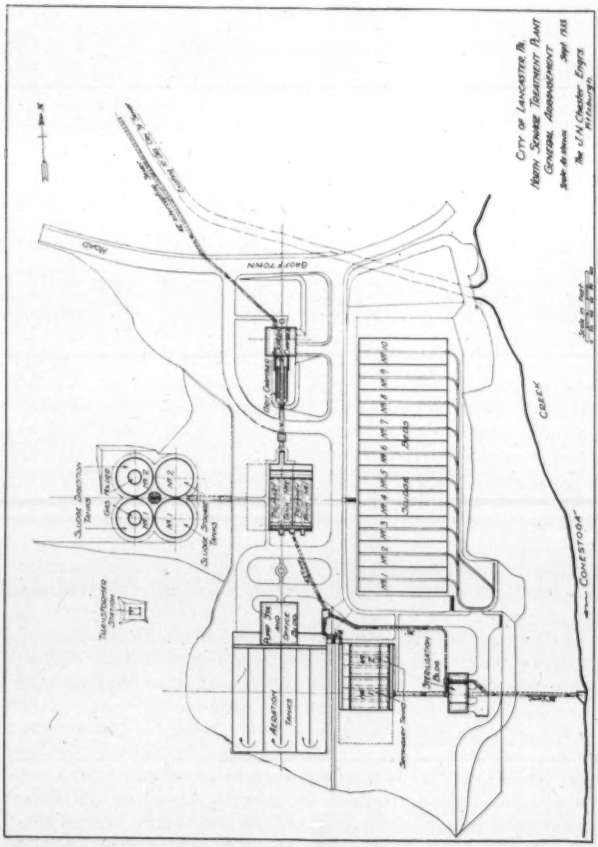

CITY OF LANCASTER, PA.
NORTH SEWAGE TREATMENT PLANT
GENERAL ARRANGEMENT
Scale As Shown
Sept. 1933
The J.N. Chester Engrs.
Pittsburgh
ROAD
GROFFTOWN
CREEK
CONESTOGA
SLUDGE BEDS
AERATION TANKS
STERILIZATION BLDG.
SECONDARY TANKS
SLUDGE DIGESTION TANKS
SLUDGE STORAGE TANKS
TRANSFORMER STATION

FIG. 1.

result of the study and report, was $3,250,000, of which approximately two-thirds was to be spent for the sewerage system, including the sewage treatment works and sewage pumping stations, and one-third for the water department improvements. The issue was placed before the people through the early spring months of 1931, and after an educational campaign lasting six or seven weeks, the voters approved this bond issue with a vote of three to one in favor, on March 17, 1931. That this action was timely and wise, no one can gainsay for the depression continued through the years 1931, 1932 and 1933, and prices continued to drop so that unemployment in the City of Lancaster was reduced materially by the construction program carried out through these years, and the taxpayers received more for their money than would have been possible since before the great war, or for almost twenty years.

Sewerage System.—As the result of the program of improvements, 14.78 miles of sewers and force mains have been completed, including 8756 feet of 10- to 14-inch cast iron force mains, 42,058 feet of 8- to 24-inch sanitary sewers and interceptors, and 27,239 feet of 30- to 96-inch concrete replacement and relief sewers. Twenty-four separate contracts were let for the construction of these sewers, costing a total, according to the final estimates, of $686,317, in addition to the street repaving item of $60,800, which work was done by the street department but charged to the bond issue.

Three sewage pumping stations have been built, one known as the Little Conestoga Sewage Pumping Station, another as the Stevens Avenue Sewage Pumping Station and the third as the Susquehanna Street Sewage Pumping Station. All stations are fully automatic in type. The Little Conestoga Station is the largest of the three and includes three sewage pumps of the non-clogging type, one having a capacity of 500 g. p. m. and the other two, each, a capacity of 1000 g. p. m., when pumping against a total head of 160 feet. The station is equipped with a chlorine machine, oil heating system, sump pump, crane, Venturi meter, toilet room and miscellaneous equipment necessary to make a complete station. The Stevens Avenue and Susquehanna Street Sewage Pumping Stations are the same in size and are similar in construction and type. Each is equipped with two non-clogging, horizontal, centrifugal pumping units, each having a capacity of 850 g. p. m. against a heat of 129 ft. at the Stevens Avenue Station, and 700 g. p. m. against a head of 101 ft. at the Susquehanna Street Station. Duplicate vacuum priming pumps, an orifice meter, interceptor control works, toilet rooms, electric heating and other miscellaneous accessories make up the equipment of the station. The cost of the Little Conestoga Sewage Pumping Station was $46,800; of the Stevens Avenue Station, $16,500; and of the Susquehanna Street Station, $17,400. The Little Conestoga Sewage Pumping Station has been in operation for some

months, while the Stevens Avenue and Susquehanna Street Stations are ready to go into operation at any time they may be called upon.

Sewage Treatment Plants.—The study developed that the most economical installation was the construction of two sewage treatment plants, one located in the northeast section of the city and known as the North Sewage Treatment Works and the other located south of the city along the Conestoga Creek and known as the South Sewage Treatment Works. Each plant is designed for a normal capacity of 6 m. g. d. The topography of the city combined with the already existent outfall sewers at Clay Street and Water Street, with the limited land areas available in Lancaster and vicinity, made it economically impractical to install a single sewage treatment works at any available location. The study further developed that the activated-sludge process was the best suited for the City of Lancaster, because of its lower first cost, the high degree of purification desirable for a small stream such as the Conestoga Creek, the flow of which in dry summers is very low, and the elimination of odor nuisances such as afflict trickling filter type plants from time to time.

The sewage treatment works were designed for 1945 conditions, when it is expected that a population of 29,000 will be connected to the North Sewage Treatment Works and 54,500 to the South Plant. Each plant is arranged so as to permit of convenient extension for treatment of sewage from a combined ultimate population of 110,000, anticipated in the year 1970, at which time it is estimated that the sewage flow to the North Plant will be 8.2 m. g. d. and to the South Plant 8.65 m. g. d. The weir measurements indicated that the flow, in November, 1930, was 3.25 m. g. d. for a six-day average from the Clay Street sewer 3.61 m. g. d. for a seven-day average from the Water Street sewer and 194,000 g. p. d. for a six day average from the Stevens Avenue Sewer. The Susquehanna Street sewer was estimated to flow at an average of 50,000 g. p. d.

It is the intention to permit storm flow to pass through the screen house and primary tanks to the extent of 12 m. g. d., or two times the normal capacity of each plant, although the structures, as now designed, so far as the hydraulics are concerned, will permit of passage of 16 m. g. d., or two times the ultimate capacity of the sewage treatment works. Both the North and South Sewage Treatment Works are exactly alike as regards capacities of main units and structures, except that the south plant includes the sewage pumping station and appurtenances located in the aeration pipe gallery. Although the population contributing to the south plant will be almost double that contributing to the north plant, the suspended solids in the sewage reaching the south plant, in parts per million, will be about 15 per cent less than at the north plant, and the sewage flows at both plants for the present will be almost equal. The biochemical oxygen demand of the sewage discharged from the Water Street sewer is

somewhat greater than that of the Clay Street sewer due to the small packinghouses and other industries contributing to the Water Street sewer.

The North Treatment Works were designed on the basis of a sewage having the following characteristics:

Suspended Solids	150 p. p. m.
Organic Nitrogen and Free Ammonia	34 p. p. m.
20 Day B. O. D. (Equivalent)	200 p. p. m.

The South Treatment Works were designed on the basis of

Suspended Solids	125 p. p. m.
Organic Nitrogen and Free Ammonia	39 p. p. m.
20 Day B. O. D. (Equivalent)	337 p. p. m.

Bids were taken on both the revolving and conveyor type mechanism for the grit chambers, primary tanks and final settling tanks. On the basis of the bids received on both the equipment and general construction work, the contracts were awarded for the installation of conveyor type mechanisms.

Diversion Works and Interceptor.—At the North Plant a dam constructed in the 10-ft. diameter Clay Street sewer diverts the flow by means of automatic, float-operated control gates, made by Brown & Brown. The gates are equipped with coarse screens and stop logs for bypassing the treatment works, and have a capacity of 16 m. g. d. or two times the ultimate normal capacity of the plant. A 42-inch concrete interceptor, approximately 1600 ft. long, carries the sewage to the screen house.

At the South Plant a dam has been built in the Water Street sewer, which is 10 ft. by 20 ft. at the point where the relief sewer joins the old sewer. This dam diverts the sewage through a McNulty automatic float-operated regulator to the 36-inch concrete interceptor, approximately 1600 ft. long, of which over 300 ft. is in tunnel through solid rock, immediately adjacent the pump pit located in the aeration pipe gallery. Both interceptors are designed for an ultimate capacity of 16 m. g. d.

Screen House.—In the screen house are located two mechanically cleaned screens with clear bar openings of $^3/_4$ inch. The maximum velocity through the net area will be 2.5 ft. per second. An incinerator, also located in this building, is designed for the destruction of screenings, scum and grit. The rated capacity is 300 pounds per hour with a minimum grate rating of 13 pounds per square foot per hour. Sewage gas will be used for fuel but provisions are being made for the burning of coal in the absence of sewage gas.

Grit Chambers.—The grit chambers consist of two channels, each equipped with conveying mechanism for carrying the grit from the chambers to the screen house, where it is deposited on the basement

floor. At this point the grit may be shoveled into cans and, by means of an overhead runway, transferred to the charging opening of the incinerator. A proportional weir is provided at the effluent end of each grit channel. Each channel is designed for a minimum flow depth of 1.50 ft. and a maximum of 3.56 ft. and for velocities ranging from 0.6 to 0.9 f. p. s.

Primary Sedimentation and Grease Removal Tanks.—Two tanks have been provided for the present, having a combined capacity of 396,000 gallons, which gives detention periods of 1.6 hours and 0.8 hour at flows of 6 m. g. d. and 12 m. g. d., respectively. The piping connections, channels, weirs and tanks have been designed to permit a flow of 8,000,000 gallons through either tank. Diffuser plates have been provided in the influent flumes stretching across the entire width of group of tanks for the purposes of keeping the solids in suspension, assuring proper sewage distribution between the two tanks, and, finally, to permit of grease removal by means of aeration. The grease is concentrated at the effluent ends of the tanks where mechanism has been provided for skimming the grease to the side of the tank, from which it is removed through an 8-inch pipe and enters a scum pit. The grease is removed from the scum pit to a can and then transported to the screen house for incineration. The detention period in the influent flumes will range from a maximum of 11 minutes when the flow is 1.6 m. g. d. to a minimum of 1.1 minutes when the flow is 16 m. g. d. The air requirements of the influent flumes have been designed for a range of 0.03 to 0.06 cu. ft. per gallon of sewage.

Aeration Tanks.—The three aeration tanks have a total capacity of 630,000 gallons, representing a detention period of 6.3 hours at 6 m. g. d. with 20% return sludge and 3.9 hours at 9 m. g. d. with 30% return sludge. Each tank has been designed for a maximum flow of 4 m. g. d. The ratio of plates to tank area is 1:11.6. The air requirements have been designed for a range of 0.75 to 2 cu. ft. per gallons of sewage. The aeration pipe gallery extends across the entire width of the three tanks, and is housed, in part, within the main building for a total width of 52 feet of the middle section, but on either end the pipe gallery is covered by a concrete slab provided with ventilators, exits and insulation against condensation. At the South Plant, four vertical sewage pumps are being installed in the aeration pipe gallery—two having a capacity of 3 m. g. d. each, and two 6 m. g. d. each, taking their suction from either of the two sewage wells located beneath the pumps. The main 36-inch interceptor is divided into two branches—one to each sewage well in which is located a 24-inch sluice gate at the end of the branch. The pumps are designed for automatic, variable speed control with float tubes, switches and other accessories. An air meter and a sewage meter is provided for each aeration tank, and another meter for auxiliary air. Special attention has been given to the matter of throttling valves located on the air lines. It has been found that

the ordinary angle and globe valves have very little accuracy of regulation in their throttling action, thus making it impractical to obtain any accurate regulation of the amount of air reaching the individual sets of diffuser plates. As a consequence, throttling valves of special design have been incorporated in all air lines, even those of smaller size feeding the diffuser plates located in the flumes. The main air piping in the tanks is located at the bottom of the aeration tanks as are the control valves, but the stems for the latter are extended to the walkways at the top of the tanks. All tanks are equipped with drains and the bottoms are sloped toward the pipe gallery for drainage.

Final Settling Tanks.—The two final settling tanks have a combined capacity of 539,000 gallons, representing a minimum detention period of 1.1 hours at 9 m. g. d. with 30% return sludge and a maximum of 1.8 hours at 6 m. g. d. with 20% return sludge. The settling rate, on the basis of a 6 m. g. d. flow with 20% return sludge, is calculated to be 1200 gallons per square foot per day; at 9 m. g. d. with 30% return sludge, it is 1950 gallons per square foot per day. Skimming troughs have been provided along both sides of each tank for a distance of 47 feet, measured from the effluent end, with a connecting cross trough located 14 feet 6 inches from the effluent end. Each tank is divided into three sludge mechanism flights; each tank being 44 feet wide by 68 feet long, inside measurements, with a flow line depth ranging from 11 feet 9 inches at the effluent end to 12 feet 3 inches at the influent end. The influent weir of one of the tanks, for its full width, is divided into three parts, each part of which is designed to operate as a tightly closing structural steel sluice gate, to permit accurate weir adjustment and also to serve as shut-off gates. A sump provided in the effluent channel common to both tanks, for connection with the effluent sewer, is lined on all sides and bottom with white enamel brick. The influent channel common to both tanks is equipped throughout its length, corresponding to the width of both tanks, with diffuser plates. Each tank is provided with a set of sludge level indicators consisting of six individual pipes reaching to various depths of the tank and connected with an air line serving as an air lift, to bring to the top of the pipes the sewage at the various depths. This will be in constant operation, and will show at a glance the condition of sludge at the various depths.

Sterilization Building and Tank.—The effluent from the secondary settling tanks may be discharged directly into the creek or may be passed through the sterilization tank where chlorination is accomplished by the chlorinated lime method of treatment. The tank has a capacity of 69,000 gallons with a rated detention period of 16.3 minutes at 6 m. g. d. and 10.9 minutes at 9 m. g. d. A building covers the entire area of the tank and houses two vacuum-type chlorine machines and a scale for the use of ton containers of chlorine; two dry-feed lime machines; a centrifugal

pump to serve the lawn sprinkling system; and chemical storage space. The building is extended on either side a width of 13 feet to provide separate rooms for the storage of chlorine containers, and garage service. This building is heated from the central heating plant located in the main building. The centrifugal pump serves the lawn sprinkling system extending throughout the grounds of the sewage treatment works, for the delivery of treated sewage taken from the sterilization tank—thus not only accomplishing economies as compared with the use of filtered water for this purpose, but also serving to give the lawn the benefit of any fertilizing value that may be left in the treated sewage.

Sludge Digesters and Gas Holders.—The two sludge digesters are each 50 feet wide, inside diameter, and $18^1/_2$ feet deep at the side walls. Each is covered by a concrete slab roof in the center of which is located a gas holder 20 feet in dimater, 17 feet, 4 inches in height and having a capacity of 5500 cubic feet. Each gas holder is capable of giving a gas working pressure equivalent to 17 inches of water. The combined capacity of both digesters is 80,000 cubic feet, which for the north plant is equivalent to 2.75 cubic feet per capita (1945), and for the south plant is 1.46 cubic feet per capita. The digesters are heated by means of hot water supplied through four copper coils in each tank, manifolded in the operation gallery for proper distribution and control. The gas will be stored in the gas holders and used for the building heating system, for heating the digesters and also for supplying fuel to the incinerator. An operating pipe gallery is located in the space formed in the center by the rounded sides of the two sludge digestion tanks and the two sludge storage tanks. Over the pipe gallery is superimposed a brick building with octagonal sides and a sloped glass roof, supported by structural members covered with copper metal work wherever exposed on the exterior.

The digestion tanks are provided with supernatant drains, sludge sampling pipes, entry manholes, drains, gas meters, flame traps and other accessories. All piping is cross connected so as to give a maximum of flexibility. The pipe gallery may be entered through the building at the ground level, at the top of the tanks, or by means of a reinforced concrete pipe tunnel extending from the pipe gallery to a point near the primary tanks where a surface entry is provided at ground level.

Sludge Storage Tanks.—Each of the two sludge storage tanks is 50 feet in diameter and 20 feet 5 inches deep at the side walls, with a combined capacity of 84,000 cubic feet, or 2.9 cubic feet per capita (1945) for the North Plant and 1.55 for the South Plant. The sludge tanks are without cover and without sludge heating, being designed to serve in effect as two-story digestion as well as sludge storage tanks. Normally, the digested sludge will be drawn from the storage tanks for drying on the sand beds.

Sludge Beds.—The sludge beds are of open type, divided into ten sections with a total area of 40,800 square feet, or 1.4 square feet per capita for the North Plant and 0.75 square feet for the South Plant, for 1945 conditions. The beds are under-drained throughout and consist of a minimum depth of 6 inches of crushed stone, 3 inches of torpedo sand and 3 inches of top sand. The side and end walls and partitions of the sludge beds consist of removable, precast, reinforced concrete slabs set in cast iron guides anchored in concrete piers. Dried sludge will be removed by hand and loaded into industrial cars, also operated by hand and running on rails extended into each of the sludge beds, terminating at discharge points either for depositing as "fill" or for loading on trucks for disposal otherwise.

Main Building.—In the main building, which is centered on the aeration tanks and adjoins the aeration pipe gallery, are housed two blowers, three primary and digested sludge pumps, two sludge return pumps, two excess sludge pumps, the sump pumps at the North Plant (one at the South Plant) and boiler room, superintendent's office, machine shop, lime conditioning room, air filter room, ladies' toilet, janitor's room, laboratories, storage room, chemist's office and toilet and locker rooms for operators. The ceiling of the blower room is provided with acoustical treatment in order to reduce the noises. The walls are of enamel tile. Each of the two blowers has a capacity of 4400 cubic feet per minute, one being a centrifugal type and the other a rotary type and both being designed for variable output. Certain economies will be possible with variable output blowers inasmuch as the air requirements may be definitely regulated at the blower itself with a consequent saving in power. Space is provided for a future blower. In the blower room is located a gaugeboard on which are mounted recording gauges for the main sewage meter and for the sludge return meters; also the control mechanism for the sludge return pumps and a double pen recording chart showing levels of sewage on both sides of the mechanical screens in the screen building. An indicating and recording gauge are provided for the sludge conditioning tank located in the basement of the main building immediately under the lime conditioning room. In the air filter room are located two sets of air filters operating in series, one being of the viscous automatic type operated by a motor and the other an airmat type. The maximum velocity through the viscous automatic filter will be 240 feet per minute and through the airmat filters, 10 feet per minute, on the basis of the capacity of one blower. On the aeration tank operating floor are located recorders for the air and sewage meters. The conventional check valves usually installed in the main air line to each of the aeration tanks and located above the operating floor level have been dispensed with. The laboratories, storage room, chemist's office and operators' toilet and locker rooms are located on the second floor. The heating system consists of two boilers: one a

combination gas and oil fired steam boiler, and the other a gas fired steam boiler, with two heat exchangers serving the digester heating system and the sterilization building heating. Four automatic sewage samplers are located in the pipe gallery of the aeration tanks—one for sampling the primary effluent, one the final effluent, one the mixed liquor and one the return sludge.

Outfall Sewer.—A 36-inch outfall sewer equipped with a bypass connection serves the North Plant and discharges directly into the Conestoga Creek; the South Plant the 36-inch outfall empties into a new 78-inch storm sewer extending 1250 feet from the Conestoga Creek up the valley in which the South Sewage Treatment Works is being built. A storm water overflow and control weir is provided in the 36-inch outfall of each plant between the primary and aeration tanks.

Costs.—The contract price of the North Plant is $416,000 and of the South Plant, $476,000, the latter including the sewage pumping station being built as a part of the plant. The laboratories are fully equipped with furniture and apparatus at both plants. More than 100,000 cubic yards of excavation are involved in the construction of both sewage treatment works, about 75 per cent of which is tough limestone rock. The construction work was started early this year and is due to be completed about July, 1934.

Personnel.—Mayor T. Warren Metzger and the City Commissioners deserve much credit for the vision and courage they displayed in furthering the project in the face of the extreme depression and consequent financial difficulties of all communities, but which at the same time permitted the letting of contracts at prices which are the lowest obtainable in almost two decades.

Commissioner Harry B. Cochran and Frank P. Sweeton, his successor in office, have been Directors in Charge of Streets and Public Improvements and Mr. Edward Edgerley has been City Engineer since the inception of the program. J. H. Miller, J. E. Kesner, A. T. Lundberg and John Sherts were resident engineers on the sewerage improvements and the author is in charge of design and general supervision, with Mr. S. L. Tolman assisting on the design of the treatment works.

Discussion

Mr. Edward Edgerley, City Engineer, Lancaster: Some of our sewers are old (some of them were built in 1870) and the majority of them are good. In the Water Street sewer there was some rock floor and some plank floor. In one place we had to take out four sections of floor and in taking out that floor we saw plenty of roots. By putting in a concrete floor we practically stopped the root nuisance. Before putting in the relief

sewers we had lots of complaints from people living along these sewers, because of flooding in that section. Two weeks ago we had the heaviest rains and there was absolutely no complaint. In inspecting the old brick sewers, of which we have quite a few built in 1870, in some of the residential sections we found root clusters growing through the sewer, some of which were 8 feet long and extended two feet out in the sewer. When we started the routine report for Lancaster we found the sewer systems were not all tied together in the residential sections. We had about 8 locations in which backing up into cellars occurred during storm flows. This year was a good test and there was only one place where there was any trouble at all.

Our automatic pumping station has been operating since January and we have had no trouble—the flood control works to perfection. The only trouble is due to the Little Conestoga Creek which normally is about 12 feet below the pipe. One night we had a 15-foot flood there. We got the sump pump working in the cellar and had no trouble in getting rid of the water which entered the station.

Mr. Laboon: I mention another feature and that is the installation of sprinkling lines throughout the grounds through which finally treated sewage will be pumped for sprinkling the lawns. We found we obtained the nicest growth of grass we ever found anywhere, by sprinkling with sewage.

Another feature to which we gave consideration was the matter of the regulation of air to the diffuser plates. I have noticed at Toronto, and also at Chicago, that with the control valves provided for the groups of diffuser plates very little regulation has been possible due to the fact that globe valves have been used. We tried in our selection of valves to insure good air control.

Mr. J. K. Hoskins, U. S. Public Health Service, Cincinnati, Ohio: I was very much interested in Mr. Laboon's paper, particularly the survey of the receiving stream, Conestoga Creek, below Lancaster. I just wonder if we do not question among ourselves sometimes, with the excellent results Mr. Laboon cited, whether we are giving due consideration to natural purification. With the oxygen content, 5 miles below, of 11 p. p. m., which was almost supersaturation, I wonder how we could defend ourselves or what we would say we are doing to improve a stream of that type. Conestoga Creek is a rather rapidly flowing stream, has considerable fall and probably re-aeration is rapid. Mr. Laboon was very wise to make a survey of that stream before the sewage treatment plant was designed and to call to the attention of the city the possibility of not going into complete treatment. There is one point to take into consideration and that is the natural purification feature, especially when we talk about taxes for sewage treatment. It places us on the defensive rather sharply

sometimes before those who object to paying taxes for, possibly, too complete treatment. In order to protect ourselves we should also have some surveys made after the plant is in operation to show what we are spending the money for.

Mr. C. L. Siebert, State Sanitary Water Board, Harrisburg: The Sanitary Water Board did make a series of traverses of Conestoga Creek prior to the operation of the sewage treatment works and later on when things are adjusted will make other surveys.

Mr. Laboon: Conestoga Creek has a fall of 2 feet per mile.

Mr. R. O'Donnel, State College: Is the stream used for recreational purposes?

Mr. Laboon: Not below the city—it could not be used; it is full of sludge.

Mr. O'Donnel: Was it so used earlier?

Mr. Laboon: Yes. We proposed complete purification and also chlorination at the upper plant, so that the stream in front of the city could be used for recreational purposes. The stream meanders and borders the city for about 7 miles. In that distance we would have purified sewage and a clean stream for recreational purposes.

Mr. Hoskins: For our own protection it is helpful to have records before treatment is undertaken and afterward to show what is being done.

Industrial Wastes and Stream Pollution

Sewage Treatment and Fish Life*

By Carl L. Hubbs

Director, Institute for Fisheries Research, University of Michigan, Ann Arbor, Michigan

My purpose in this paper is to indicate: *first*, the general failure to approach the problem of sewage treatment, in relation to fish life, with an open mind; *second*, the extreme difficulties encountered in determining the whole, varied ill-effects of sewage on fish life; *third*, the lack of any sound scientific basis for fixing a legal limit for pollution in terms of dissolved oxygen content, biochemical oxygen demand or any other single, simple test; *fourth*, the beneficial effects of sewage on fish life, in the increase of food organisms; *fifth*, the dovetailing of fishing, recreational, health and economic interests, as affected by sewage, treated and untreated.

The problem of the effect of sewage on fish life, like other problems of stream pollution, is one that requires clear, straight thinking, freed from prejudice and untainted by personal or financial interests, and coupled with good, hard scientific work. This follows not only from the difficulty of approaching this problem in a truly scientific way, but also from the inherent complexity of the effects of various types of sewage on fish life of different kinds, under varying conditions.

The effect of sewage on fish life varies greatly with the season. During the winter, when the water is very cold, fish are extremely resistant to the effects of pollution, usually surviving unless the dissolved oxygen beneath the ice is entirely or almost entirely exhausted for some time. The rapid rise in water temperature in the spring brings on a critical period, when fish are susceptible to unfavorable conditions, and often die. Again in late summer and early fall, when high water temperatures are attained, the fish show reduced resistance to low oxygen and other effects of pollution. Unless a stream or lake approaches the character of an open sewer, fish deaths in it are usually confined to a very few days in the year, when the weather is very warm and the water level low. Weeks of investigation during the summer in a given stream or lake may give little or no evidence as to any harmful effect of the sewage on fish life, though the proper combination of circumstances may suddenly lead to conditions incompatible with fish life.

Read at Ninth Annual Conference, Michigan Sewage Works Association, Michigan State College, March 30, 1933.

The effect of sewage on fish life also varies greatly with time of day. Investigators, especially those of regular habits, may entirely miss the septic conditions which may exist for parts of a day in a stream. It is not at all infrequent for a badly sewage-polluted stream to show not only saturation with dissolved oxygen, but even a marked supersaturation, running as high as 100 or 200 per cent. This condition holds especially on sunny afternoons. The same stream is very apt to show a great reduction, sometimes a complete removal of the dissolved oxygen during the night, especially toward morning. To cite an instance, I once studied the lower River Raisin below Monroe, where it is badly polluted by sanitary and paper-plant sewage. During the night the dissolved oxygen became entirely consumed, anaerobic decomposition set in, hydrogen sulphide was produced and reacted with the reduced iron salts in the water to produce ferrous sulphide, so that the water ran foul and black before daylight. Then the sunlight fell upon the water, causing the algae to manufacture oxygen, which oxidized the ferrous sulphide to form white colloidal sulphur, so that the stream ran white instead of black.

It is extremely difficult to determine the kind and degree of harm that sewage may do to fish life. When the fish are actually killed outright and in quantity, the harm is obvious. But when the fish are slowly killed off, the deaths may pass unnoticed, or may be attributed to causes other than pollution. The sewage may change conditions so that the fry only are killed, and the dead fry will not ordinarily be seen. Or the spawn may be prevented from hatching, or the development may be made abnormal, so that malformed fish result—we have often noticed a high incidence of abnormal or teratological fish in polluted waters. Or the natural spawning beds may be covered over by a deposit of septic sludge, in which the eggs cannot hatch. Even if the fish clear their "beds," or redds in technical parlance, the fine sludge-silt will likely shift enough to cover and smother the eggs.

The pollution may kill the animal life on which the fish normally live, thus depriving them of nourishment. For this reason or perhaps because of the altered chemical content of the water, fish may become much dwarfed in polluted waters. Thus in the River Raisin I found two or three year carp below Monroe to be about the size of yearling carp above town, and to have only a fraction of the weight shown by the carp of their own age in the unpolluted water. This means a loss in total production, which in the case of valuable fish may well reach serious proportions, even where few fish are actually killed.

Certain chemicals, even in minute quantities, have been known to affect the taste of fish so as to prevent their sale.

Another probable effect of sewage on fish life involves the driving off of the fish. Fish unquestionably show a negative reaction toward water

badly polluted with organic wastes, for they swim away from such waters. Thus in the mill-ponds of the River Raisin, when badly polluted by organic wastes, I have seen thousands of fish butting against the shores in their efforts to escape. Even if no definite negative reaction causing the fish to swim directly away is called forth, the fish are likely to become restless. This may interfere with growth or make the fish an easier prey to fish-eating birds or predacious fish. They will likely continue the uneasy movements until they finally land in unpolluted waters, where they will then settle down as good fish citizens, finding their retreats, feeding grounds, etc.

These nervous movements which may bring the fish to harm may be incited by extremely minute quantities of pollution. In experimenting with the effect of ozone on fish life, I found that less than 0.1 part of ozone in one million of water was sufficient to kill small fishes, but that much smaller quantities, perhaps less than 0.01 p. p. m., too little to be recorded by a very delicate chemical test, sufficed to throw the fish into nervous movements, from which there was no quick recovery. Since such excessively minute quantities of ozone will produce an obvious effect on fish movements, it is at least possible that traces of other chemicals in sewage may cause fishes to vacate waters which will not kill them.

A very indirect but probably real way in which sewage harmfully affects food and game fish is through the increase in coarse fish, such as carp. Such coarse fish probably tend to decrease the better fish, by eating eggs or fry, by cleaning out the shallow weed beds so that the young game fish will be deprived of their normal and needed shelter, by competing for food, or in some other manner.

Another way in which sewage may affect fish other than by killing them lies in the increased incidence of disease. This is often to be observed in polluted waters. We have already mentioned that abnormally formed or monstrous fishes are sometimes common in polluted waters. Other diseases are also frequent in polluted waters. These are in part due we may suppose to the weakened condition of the fish. Parasitic worms may abound, especially the species which produce little black cysts on the skin. Those species of parasites may abound in polluted waters, because they must first live in a snail before infecting fish, and snails are often increased by pollution. Bacterial diseases of fish are also common in polluted waters. One such disease for instance, causing the fins to be eaten away, was found very prevalent in the heavily polluted lower River Raisin. It is quite possible that some pathogenic bacteria are not very specific as to their hosts, and that they may be actually contributed to the stream by the city sewage. Or the sludge deposits or the growths of slimy fungi in the polluted waters may very well harbor the disease-producing microorganisms, so as to render easier the infection of new fish. (The slimy

deposits in fish troughs have been shown to uphold a growth of the bacterium causing a very serious gill disease in trout.) The bacteria concerned may even multiply in the slime or sludge.

I could cite other indirect ways in which sewage may harmfully affect fish life. But I have perhaps gone far enough to show the extreme complexity of the problem, and the difficulty of determining just what harm the pollution may do to the fish life. Any disturbance in the natural balance of plant and animal life in the streams or lakes may seriously affect the fish life. The indirect effects of sewage in depleting or eliminating the fish supply may well be more important than the direct killing effect.

Since it is so hard to determine the way in which pollution harms the fish life, or the degree of harm produced, it follows that it is extremely difficult to fix a definite standard of allowable pollution. It is the very natural desire of sanitary engineers to have a definite measure of degree of pollution which may be regarded as legal. But the great seasonal and hourly variations in dissolved oxygen content, or other pollution indices, make critical, or extreme, or even representative determinations hard to obtain. The effects of pollution on the fish life other than killing them, and the very indirect effects resulting from the disturbance of the balance of nature, make it difficult to estimate whether a given degree of pollution will be harmful to fish life.

The engineers or administrators or legislators who wish to fix a legal standard limit for pollution usually want to base the limit on dissolved oxygen content. They come to the fishery workers with the request for information as to the lowest amount of dissolved oxygen which fishes will tolerate without material harm. The desire is to adopt a certain legal standard, such as 2, 3 or 4 p. p. m. or some other figure. The limit of 4 p. p. m. has been particularly mentioned in this state. While we do not wish to say that administrative expediency may not require such a limit, we must express our opinion that any definite limit, of 2, 3, 4 or 5 p. p. m., would have to be made without real scientific foundation. In addition to the difficulties of determining the low values existing in the stream, or of estimating the manner or degree of harm done by any degree of pollution, we encounter the difficulties arising from the varied effects of the different elements in the sewage causing the pollution, especially if the sewage be untreated.

We certainly cannot give the engineer any definite figure on the amount of dissolved oxygen which is just sufficient to support fish life. An amount of say 2 p. p. m. may just kill a given kind of fish in a reasonable experimental time (say 36 hours). But other fish may not be killed with this treatment; other kinds may die more quickly. The killing limit of dissolved oxygen varies of course with the temperature: the higher the temperature, the more oxygen is required to sustain life. Winter caught

fish are very resistant to low oxygen, but are especially susceptible when subjected to rapid temperature increases, either in nature or in the laboratory. Spawning fish are easily killed, and fish eggs or fry may succumb to dissolved oxygen values well above those which kill the adult fish.

Even if we take fish of a single species at a single age and season, we cannot give *the* death point in terms of low dissolved oxygen. The amount of oxygen just sufficient to sustain the fish's life depends also on the other substances dissolved in the water. The amount of dissolved oxygen necessary is supposed to increase if the amount of dissolved carbon dioxide is increased. In some experiments with sugar-plant wastes we found that sunfish would live many hours in good "control" water containing only a fraction of 1 p. p. m. of dissolved oxygen. But other fish, quite similar, were quickly killed in dilutions of an organic waste (Steffen's waste from a sugar plant), in which the oxygen level was held up to 5 or 6 p. p. m. by compressed air. In some natural waters which are almost devoid of dissolved oxygen, fishes may continue to live for considerable periods of time, merely showing their distress by lapping at the surface. In other circumstances they may be killed by organic pollutions when the oxygen level is moderate. Thus in Iowa it has been found that fish may be killed by decaying algae, even though the algae not dying are able to hold the oxygen level above 4 p. p. m. (obviously through the process of oxygen production by the live algae, in the sunlight, in quantities sufficient to more than take care of the decomposition of the dead algae). It is possible, of course, to determine for fish of a given species, age, sex and season, just how little dissolved oxygen is necessary to support life, under any given conditions. But these conditions vary tremendously with the stream, the season and the amount of natural pollution, as well as with the nature and amount of the pollution substances being discharged into the stream. Since we cannot readily determine the amount of dissolved oxygen just low enough to kill fish in natural waters, we certainly would find it a very difficult task indeed to determine the less direct, but perhaps more important, indirect effects on fish life of any given low value of dissolved oxygen.

In some states, the attempt has been made to determine a low oxygen value allowable for polluted waters, using biochemical oxygen demand in conjunction with dissolved oxygen. The proposed value has been called the "fish zero," or better the oxygen reserve. This is obtained by subtracting the B. O. D. from the dissolved oxygen. If the result is over 3.0 p. p. m., the condition is termed satisfactory; if under 3.0 p. p. m., unsatisfactory. This method has the advantage over the simple dissolved oxygen standard, in that it makes it less important to be on the ground when the D. O. is at its lowest point. The B. O. D. tells after a fashion what may be expected to happen to the D. O. under unfavorable conditions. But it does not follow that a stream with an oxygen reserve of

under 3.0 p. p. m. is unfit for fish life. The water may carry a B. O. D. higher than its D. O. (thus giving a negative value of oxygen reserve), yet be rather healthy for fish, if the stream is frequently well aerated by flowing over riffles or dams.

Other states, as New York, have frankly recognized the extreme difficulty of fixing a legal limit to pollution on a chemical basis. New York has been using instead the "minnow test," to determine if there has been a violation of the law prohibiting the discharge of substances injurious to fish life. In the test it is determined whether minnows die when confined in a live-box in the water. The difficulties in this test are perhaps as great as in the chemical tests. Any one who has tried to keep minnows alive in live-boxes, knows how difficult it is to do so, even in unpolluted streams. Then different species of minnows vary greatly in their resistance. Furthermore, whether or not the minnow will die in the test will certainly depend on how and where caught, how long and in what manner treated while being transported for the test, and on how great a difference exists between the native and the polluted stream, in respect to temperature, chemical content, etc. The pollution may also affect the fish injuriously in other ways than by causing death, or it may be difficult to make the "minnow test" at the right time and place. So far as I can see, no simple test for the lower limit of allowable polution may be fixed on any good scientific basis.

Any estimation of the effect of pollution on fish life is complicated by the fact that most sewage, especially sanitary sewage, is at least potentially beneficial to fish life. This is a point which is seldom even mentioned. It would be regarded as a heresy by the anti-pollution crusader. It is a light on the subject against which even supposedly scientific investigators have blinded themselves.

The beneficial effects of sewage on fish life lie in its fertilizing qualities. Sanitary sewage is very rich in nitrogen, and has a considerable content of phosphorus and a very small amount of potassium and other fertilizing elements. Aquatic crops can be increased just as land plants by the addition of these elements to the nutritive medium. Numerous laboratory experiments have shown that the addition of nitrates and phosphates stimulate the aquatic growths. It is becoming the standard practice in fish culture to fertilize the rearing ponds with nitrogen-rich meals, such as soy-bean meal, with phosphate fertilizers and with sheep manure. Since sanitary sewage carries very similar substances, it is clear that it is also capable of increasing fish production, through the increase in the plants and then of the small animals on which the fish feed. The accumulated experience of the centuries in Oriental fish culture has demonstrated the effect of sanitary sewage on fish production. Over there it is the custom to place the privies over the innumerable little fish ponds, so as to fertilize the ponds directly. The reason why a certain Scandinavian lake produces

an unusually high fish yield in pounds per acre per year was found to lie in the fact that the small village on the lake discharges its sewage into the lake. The fact that Lake Erie has over the years yielded approximately as much poundage of fish as all the other Great Lakes combined may well be due in part to the fertilizing of this lake by the large human population which surrounds it. After the sanitary sewage of Chicago was diverted into the Illinois River, a marked increase in the commercial fish yield of that river was recorded.

This increased yield of the Illinois River, however, did not hold up. Gradually a deposit of septic sludge accumulated near the head of the river, making that end of the system unsuited to fish life. As the sludge accumulated it advanced down-stream, year by year lengthening the virtually fishless section of the stream and shortening the lower portion of increased fish production. This process had continued until a few years ago, so that only the lower section of the stream remained in fish production, though this short section still showed a high production. Now, as Chicago is installing sewage treatment, the zone of fish production is gradually progressing up-stream, as the sludge is being removed faster than it accumulates.

The accumulation of sludge is one of the most baneful effects of untreated sewage. The septic bottom putrefies under anaerobic conditions, producing substances toxic to fish life and obnoxious to man. The formation of sludge in the great rivers is accelerated by erosion and silting. The fine soil particles pick up the sewage particles by adhesion, and carry them down to form a slowly decomposing sludgy mud of high organic content. This suffocates the useful bottom life, and in decomposing makes the overlying water less fit for fish life, or for human use and enjoyment.

Incomplete treatment of sewage is poor economy. It is at best an alleviative and not a cure. The makeshift of merely ponding sewage rich in organic wastes is particularly unsatisfactory. Anaerobic decomposition will set in, producing a local nuisance and at times discharging an effluent into the stream which may be more toxic than the original raw sewage. Then accidents occur. An innocent muskrat may bore his tunnel through the retaining dike. No little Dutch boy being handy to plug the hole, the whole contents of the retaining pond may be discharged into the stream. The flood of toxic waters then rushes down-stream, cleaning out the whole stream of its fish life. This is not mere theory. It has happened a number of times in our own state. For instance, in 1921, the dike of the retaining pond of the sugar plant at St. Louis broke, resulting in wiping out much of the fish fauna of the Pine River.

The utility of thorough sewage treatment is now obvious. It produces no noxious sludge deposits. The oxidized wastes do not cause excessive oxygen loss in the stream, but prevent excess accumulation of carbon di-

oxide and other products of aerobic decomposition, and eliminate the more obnoxious products of anaerobic decomposition. The larger part of the nitrogen, phosphorus, potassium and other desirable fertilizing elements are retained in the effluent of the treatment plant, and the nitrogen and phosphorus are added in the oxidized and soluble form of nitrates and phosphates, which are directly utilizable by the water plants. These in turn support the animal life on which the fish feed. The fish can spawn on the cleaner bottom or in the weed beds, according to their way, the young fish will find weeds in which to seek shelter and the minute organisms on which they grow, and the larger fish will find the larger food which they prefer. The treated sewage is thus turned into increased fish production.

The thorough treatment of sewage also eliminates the unsightly solids which, floating by, disgust the stream-side visitor. It eliminates the putrefying sludge, with its obnoxious appearance and odor. The water retains its oxygen, so that the organic matter remaining is disintegrated by aerobic decomposition, thus avoiding the production of the unsaturated compounds, such as hydrogen sulphide, which are also obnoxious. The pathogenic bacteria are sufficiently destroyed to make the waters safe again for boating and swimming and much more satisfactory for city water supply.

Thus the interests of better fishing are dovetailed with other recreational interests, and with property values. Summer cottages will spring up along the purified stream away from the cities, and in and near the cities the stream side property will be available for better homes. A comparison of the home site values along the Red Cedar just above East Lansing and along the Grand below Lansing will suffice to show that the elimination of pollution has a real dollar value.

But perhaps even more important than the increased economic values which result from complete sewage treatment are the increased recreational values. A beautiful stream-side park in a city can serve mankind more significantly even though less concretely than a mere increase in monetary wealth. Our strained and industrialized people need recreation in increasing amount. Where can man enjoy a day more pleasantly than along a beautiful stream, chosen trysting place of young, favorite subject of the artist? And if good fishing can be in order, may not the enjoyment of the day be perfect?

Editorial

The Middlesex Project

It will be interesting to American readers to learn of the great sewage treatment project now under construction in the County of Middlesex, west of London. This work is under the direction of John D. Watson, who is well known for his achievements in sewage treatment and sludge disposal at Birmingham. Mr. Watson recently described the Middlesex scheme in a paper before the Royal Sanitary Institute. This paper is abstracted in this issue (page 1054) and the abstract is augmented by a map and diagrammatic layout received from Mr. Watson just before this issue went to press.

A project involving the expenditure of four and a half million pounds is rather impressive, even in America. In addition to the responsibility for such an outlay, the technical problem is quite difficult. It is interesting to note that Mr. Watson has recommended the activated-sludge process. This decision emphasizes the preëminence of this process for large installations. The scheme comprises treatment at the Mogden site and disposal of sludge at Perry Oaks, seven miles away. In this plan the Middlesex scheme follows precedent at the Chicago North Side plant, where the activated sludge is pumped seventeen miles before it is dewatered. Likewise at the new Cleveland activated-sludge plant on the lake shore, the sludge will be pumped thirteen miles to the Southerly Works for disposal. This segregation of sludge treatment is a logical procedure where the treatment plant must be located near built-up or high class communities. The Birmingham experience lent confidence to the more recent decisions to adopt this method of sludge disposal.

Details of the digestion and drying plant at Perry Oaks will be awaited with interest. Apparently the Birmingham two-stage separate digestion procedure is to be adopted. Mr. Watson will have to take account of the high moisture content of digesting activated sludge, as compared with the settled sludge digested at Birmingham. Likewise there will be less gas per unit of volatile matter. The tried and tested procedure at Birmingham is a noteworthy precedent, and it will be of interest to learn how this procedure is to be modified at Perry Oaks.

The Middlesex project is a fitting tribute to Mr. Watson's ability. He has visited America several times and those who became acquainted with him during his visit here two years ago will be pleased to learn of the progress on this large undertaking, and all will wish him success in carrying

through England's greatest sewage disposal project in the past twenty years.

Vacuum Filters

The vacuum filter has been an important factor in the development of a mechanical process for the disposal of sludge. Recent investigations of the use of vacuum filters for the dewatering of sludge are reviewed briefly in this issue by E. D. Flynn. The continuous production of dewatered sludge by vacuum filters, their high capacity and low labor requirements contrast favorably with the batch production of filter presses, with their higher labor costs and longer cycles of operation. The early work on activated sludge at Chicago and Milwaukee showed that a thick cake in filter presses would be of uneven solid content and a long pressing time was necessary. A thin cake in presses greatly cut down the capacity, but on the continuous vacuum filter a thin cake could be produced without a serious impairment of the cake production per unit. Vacuum filters have therefore been used exclusively for large-scale dewatering of activated sludge, although a large hydraulic bag press was used for six or seven years at the Des Plaines plant of the Sanitary District of Chicago.

Vacuum filters are limited to low pressure of 14 lb. per sq. in. or less, while presses can be used with considerably greater pressures, up to 100 lb. per sq. in. or more. However, unless the lost time in filling and dumping can be reduced materially, and unless the labor requirement for such operations can be lessened, pressure-type filters will probably not be able to compete with vacuum filters. On the other hand, vacuum filters are apparently limited in producing a comparatively dry cake by the low pressure available, while pressure-type presses can undoubtedly lower the range of moisture contents on most types of sludges. The time factor is the limiting obstacle for presses.

The importance of sludge conditioning is pointed out in Mr. Flynn's article. This requirement is fundamental in the practical filtration of sewage sludge. Any type of vacuum filter or press is soon out of commission on untreated sludge.

With regard to Mr. Flynn's preference for filtration of digested sludge, rather than raw, much of his preference is based upon the estimates of peak loads with raw sludge, which must be handled by spare equipment above the average requirement, while digesters are presumed to smooth out the peak loads and permit a lower initial installation of equipment. These estimates of peak loads with raw sludge are subject to confirmation by actual operation, consequently a decision as to the relative merits of filtration of digested *vs.* raw sludge should be held in abeyance. There

are many arguments pro and con—such as rate of filter production *vs.* cost of conditioner, gas from digesters *vs.* higher B. t. u. value of raw sludge, and possibility of dumping filtered digested sludge *vs.* necessity for incineration of undigested sludge. Mr. Flynn's paper is provocative of thought and discussion along these lines and as such is valuable in furthering the progress of sludge disposal.

Employment Service

(1) DESIGNER thoroughly experienced in design and construction of sewage treatment plants. Just completed one year with general contractor on sewage treatment plant job. Previous four years drafting and design work in sanitary engineering. Total experience twelve years since graduation. Age 37. Married. Assoc. Mem. A. S. C. E.

(2) M.S. in SANITARY ENGINEERING, 1932, Michigan State College. Seven years with the Michigan State Highway Commission. Municipal engineering, including construction of water mains and sewers. Assistant instructor in sewage operators school. Publications on trickling filters and stream pollution. Age 31. Married.

(3) SANITARY ENGINEER, graduate M. I. T., four years experience in design of sewers and sewage treatment works, five years experience in investigating industrial wastes, designing and operating sewage testing stations, and investigating and developing methods and apparatus for sewage treatment. Three years as asst. supt. of large activated-sludge plant. Desires position to design or operate treatment works or to aid in the development of new processes and apparatus for sewage treatment. Age 36. Married.

(4) CHEMIST AND BACTERIOLOGIST, university graduate, six years superintendent of water filtration plant, past five years in sewage works laboratory, in charge of plant control. Recent experience in sludge filtration and disposal. Age 37. Married.

(5) SANITARY ENGINEER, M.S. from Michigan State College. Experience in highway and railway work. University work in soil bacteriology. Age 25. Single.

(6) SANITARY CHEMIST AND BACTERIOLOGIST, B.S. in Chemical Engineering, M.S., four years experience in sewage and water treatment, principally research and development at state experiment station, recently with prominent consulting sanitary engineer, publications. Age 27. Single.

(7) SANITARY ENGINEER. More than ten years experience in designing, building and servicing mechanical equipment used in sewage treatment works, such as screens, clarifiers, digesters, aerators and pumps. Design and construction of paper mill and beet sugar factory. Age 37. Married.

(8) SUPERINTENDENT of sewage works. Ten years experience as Superintendent of small Iowa sewage treatment plant. Has also had charge of municipal garbage incineration works. References. Age 39. Married.

(9) SANITARY ENGINEER. Technical school graduate, nine years experience sewage collection and treatment and water distribution and purification. Investigations, reports, design, construction, operation, chemical and bacteriological analyses, research and development, sanitary equipment sales and promotion. Familiar with engineering state and municipal organizations in eastern and mid-western states. Desires position as sales engineer, designer, or operation superintendent. References and details of experience on request. Remuneration secondary to permanent connection with future. Age 30. Married.

Proceedings of Local Associations

Central States Sewage Works Association Sixth Annual Convention

Indianapolis, Oct. 12–13, 1933

The Central States Sewage Works Association held its Sixth Annual Convention conjointly with the Public Health Engineering Section of the American Public Health Association at the Claypool and Lincoln Hotels in Indianapolis, October 12–13, 1933, with a registration of ninety-one.

Thursday.—At the morning session, a joint meeting with the Public Health Engineering Section presided over by C. K. Calvert, Chairman of the Central States Sewage Works Association, the following papers were presented: "Recent Advances in the Chemical Treatment of Sewage," by F. W. Mohlman, Director of Laboratories, Sanitary District of Chicago. Discussion by F. H. Waring, Ohio State Sanitary Engineer, Columbus; "Sewage Sludge Gas Utilization," by C. E. Keefer, Bureau of Sewers, Dept. of Public Works, Baltimore; "Mechanization of Sewage Treatment Works," by E. B. Besselievre, Sanitary Engineer, the Dorr Co., New York City; Discussion by H. F. Ferguson, Illinois State Sanitary Engineer, Springfield; "The Treatment of Trade Wastes," by L. F. Warrick, State Sanitary Engineer, State Board of Health, Madison, Wisconsin; Discussion by Henry Heisig, Chemist, Milwaukee Sewerage Commission.

In the afternoon a joint inspection trip included the Indianapolis Sewage Disposal and Garbage Reduction Plants and the Filtration Plant of the Indianapolis Water Company.

Following the dinner at the Lincoln Hotel Mr. Abel Wolman, Federal Public Works Engineer for the State of Maryland and Special Representative of the Public Works Administration, Washington, D. C., delivered an address, "The Public Works Administration and Your Town."

Friday.—The morning meeting was addressed by Gus H. Radebaugh, Manager of the Urbana-Champaign Sewage Treatment Works, on the subject "Selling Sewage Disposal." (Published in this issue.) The paper was discussed by H. C. Delzell, General Field Representative, American Water Works Association, Chicago. This was followed by a symposium on stimulating Public Works Administration Sewage Treatment Projects, presented by the following: L. F. Warrick, Wisconsin State Sanitary Engineer, F. H. Waring, Ohio State Sanitary Engineer, F. C. Dugan,

Kentucky State Sanitary Engineer, L. A. Geupel, Indiana State Sanitary Engineer.

City Engineer Carl Carpenter of Bloomington presented a paper, "Revenue Bonds and Sewer Service Charges at Bloomington," which was discussed by M. W. Tatlock, Superintendent of the Dayton, Ohio, Sewage Treatment Plant. (Published in this issue.)

"Sewage Service Charge Delinquencies," was the title of a paper given by W. W. Morehouse, Director of the Department of Water and Sewage, Dayton, Ohio. (Published in this issue.)

The morning session concluded with the report of the secretary and treasurer and with the reports of various committees.

At the business session which followed the luncheon, a resolution, regarding prize awards, was adopted as follows:

Awards shall be made to author-member of best paper presented at preceding annual meeting. Best paper shall be judged by following points with the percentage weights as indicated.

1. Best addition to the science and art of sewage collection and—or treatment (considering substance of paper). 70 per cent.
2. Arrangement and style of paper for clarity and freedom from unnecessary verbiage. 15 per cent.
3. Method of presentation when made at meeting. 15 per cent.

The Committee on Awards is as follows: Prof. F. M. Dawson, University of Wisconsin, Madison; E. C. Hurd, Consulting Sanitary Engineer, Indianapolis, and H. F. Ferguson, Dept. of Public Health, Springfield, Illinois.

It was decided that the Seventh Annual Convention would be held in Wisconsin, probably at Sheboygan.

After the Auditing Committee had given its report, officers for 1933–34 were elected as follows: H. F. Ferguson, Springfield, *President;* M. Starr Nichols, Madison, *First Vice President;* O. M. Leonard, Frankfort, Ind., *Second Vice President;* Gus H. Radebaugh, Urbana, *Secretary-Treasurer.*

During the remainder of the afternoon papers were presented by M. W. Tatlock, Supt., Dayton Sewage Treatment Plant, "Causes and Prevention of Sewage Plant Odors;" O. M. Leonard, Director of Dept. of Public Sanitation, Frankfort, Indiana, "Value of Sewage Plant Operation Reports;" Wm. D. Hatfield, Supt. Decatur, Ill., Sanitary District, "Determining the pH of Sewage Sludge;" and L. H. Enslow, Editor of *Water Works and Sewerage,* New York City, "Chemical Treatment of Sludge to Facilitate Disposal."

GUS H. RADEBAUGH, *Secretary-Treasurer*

Ninth Annual Missouri Water and Sewerage Conference

Jefferson City, Sept. 22–23, 1933

The Ninth Annual Missouri Water and Sewerage Conference was held in the State Capital at Jefferson City, September 22 and 23. Seventy-seven members and guests were registered at the meeting.

Five papers were presented and the rest of the time was devoted to round table discussion. H. C. Beckman, District Engineer of the United States Geological Survey, in his paper, "The Relation of Stream Flow to Public Water Supplies and Sewage Disposal," outlined the work which is being done by the United States Geological Survey and the State Geological Survey on gaging of streams and showed the value of these records to cities now having or contemplating the installation of public water supplies or sewerage systems. He also stated that the United States Geological Survey and the State Geological Survey would coöperate with cities in the erection of gaging stations on streams which served as sources of municipal water supplies or as receiving streams for the effluent from city sewage treatment plants.

In his paper, "Water Softening," F. M. Veatch, of Black and Veatch of Kansas City, discussed some of the recent trends in municipal water softening with lime. His paper was illustrated with a moving picture of the Neodasha, Kansas, water softening plant. Reference was also made to the fixed charges and operating costs before and after the installation of the softening plant.

Henry Dahm, Vice President of G. S. Robins and Company, St. Louis, Missouri, in a paper on "Notes on Odor Abatement of Open Sewers and Drainage Ditches" described some experimental work which had been done in St. Louis County on odor abatement in open sewers. The experimental work was done with sodium hypochlorite fed in solution. Mr. Dahm expressed the belief that the hypochlorites provided an inexpensive method of determining whether or not chlorination was feasible.

Colonel Hugh Miller, State Engineer for the Public Works Act, spoke on "The Public Works Act." This session was held jointly with the Missouri Public Health Association which was also meeting in Jefferson City. Colonel Miller explained the workings of the Public Works Act and urged cities to make applications as soon as possible. After his paper he answered questions coming from the floor.

Ralph Fuhrman, General Superintendent of Sewage Treatment Plants Springfield, Missouri, presented a paper "Observations on Sewage Plant Operation at Springfield." Springfield has the largest sewage treatment project in the State of Missouri. Mr. Fuhrman discussed the routine

operation at Springfield's four plants and also presented interesting data on the effect of filter loading and on chlorination.

The round table discussions, which were conducted by Earnest Boyce, Chief Sanitary Engineer of the Kansas State Board of Health, were devoted to water topics.

At the business meeting, the following officers were elected: L. P. Andrews, Sedalia, *Chairman*, Hugh Brown, Vandalia, *Vice Chairman*, Herbert Bosch, *Secretary-Treasurer*, Jefferson City. A. E. Thain, Neosho; E. S. Flannery, Platte City; A. J. Sherwood, Canton; and August Nolte, St. Louis, *Executive Committee*. Ralph Fuhrman, Springfield; E. S. Glenn, Carthage, *Representatives on Board of Control, Federation of Sewage Works Association*.

After the business meeting, the members enjoyed an inspection trip and luncheon at the filtration plant of the Capital City Water Company which supplies Jefferson City with water.

HERBERT BOSCH, *Secretary-Treasurer*

New England Sewage Works Association Fifth Annual Meeting

Worcester, Mass., Oct. 2, 1933

The Fifth Annual Meeting of the New England Sewage Works Association was held Monday, October 2, 1933, at the Hotel Bancroft, Worcester, Massachusetts. Ninety-six members and guests were registered for the various sessions of the meeting.

The first paper, "Recent Developments in Sewage Treatment," by Harrison P. Eddy, was presented by Almon L. Fales in the absence of Mr. Eddy. This was followed by a paper entitled "Effect of Sewage and Effluents on Streams," by Robert Spurr Weston of Boston. A third paper, "Safety Methods in Sewer Work," was presented by Alfred Kinsella of Boston, who demonstrated the proper use of gas masks and the correct method of giving artificial resuscitation.

Following a discussion of the foregoing papers, President Lanphear opened the business session of the meeting. The officers elected for the ensuing year are as follows: Julius W. Bugbee, Providence, R. I., *President;* Prof. Gordon M. Fair, Cambridge, Mass., *Vice President;* F. Wellington Gilcreas, Boston, *Secretary-Treasurer;* Roy S. Lanphear, Worcester, Mass., and Guy E. Griffin, Greenwich, Conn., *Directors*.

The Secretary reported a total membership of one hundred and thirty-six. After the Auditor and Treasurer had presented their reports the morning session adjourned.

The Association was the guest of the Norton Company at luncheon in the assembly hall of the plant. Mr. Aldus C. Higgins, President of the Norton Company, addressed the Association. Following the luncheon the Question Box was opened and a Round Table Discussion was led by the President.

The group was divided into small sections, and, under the leadership of guides from the Norton Company, inspected the process of manufacture of abrasive products and especially the testing of porous plates used in sewage treatment.

Leaving the Norton Company's plant, the Association went to the yard of the Worcester Sewer Department. Here they witnessed a very interesting demonstration of sewer and catch basin cleaning, given by the Worcester Sewer Department under the direction of Supt. John H. Brooks, Jr. The buildings and yard were open for inspection and the modern equipment proved of interest to all.

The Annual Dinner was held in the Ball Room of the Hotel Bancroft and was addressed by Mayor C. Mahoney of Worcester. Following the dinner, President Lanphear introduced Prof. Charles M. Allen of Worcester Polytechnic Institute, who gave a very interesting and instructive talk and demonstration on "Gasoline and Kerosene, Their Use and Abuse."

F. WELLINGTON GILCREAS, *Secretary-Treasurer*

New York State Sewage Works Association Annual Fall Meeting

White Plains, N. Y., Oct. 27–28, 1933

The New York State Sewage Works Association held its Fall Meeting at the Hotel Roger Smith in White Plains, N. Y., October 27–28, 1933, President A. F. Dappert presiding. One hundred and sixty members and guests were registered.

Following registration and a cordial address of welcome by James Berg, Secretary of the Westchester County Sanitary Sewer Commission, the convention opened with a brief business meeting and the presentation of four technical papers Friday morning. Alexander Potter, Consulting Engineer, New York City, in his paper "Joint Sewerage Works Serving Twelve Municipalities," illustrated by slides and movie films, presented many unusual features of a large sewerage project. Discussion of this paper was led by W. W. Young, Consulting Engineer, New York City. A paper on "Chemical Precipitation as an Adjunct to Sewage Treatment at Freeport, L. I." by Lawrence L. Luther, manager of the Department of Sanitation of Freeport, was received with much interest, and discussion

was opened by Weston Gavett, Consulting Engineer of New York City, and Robert N. Clark, Sanitary Engineer of Innis Speiden Company, New York City. Morris Cohn, Sanitary Engineer, Schenectady, presented a brief abstract of the Annual Report on the operation of the Schenectady Sewage Treatment Works. W. J. Scott, Director of Sanitary Engineering, Connecticut Department of Health, gave a timely paper on "Regulations Pertaining to Qualifications of Sewage Works Operators," covering the Connecticut aims and experience. Discussion prepared by F. D. Stewart, Principal Assistant Engineer, Ohio State Department of Health, was read and further discussion was presented by E. B. Besselievre of the Dorr Company, New York City.

At the luncheon Mr. Herman W. Merkel, General Superintendent of the Westchester County Park Commission, was the principal speaker, using as his subject "Landscaping and Beautifying Sewage Treatment Works."

The afternoon was devoted to a symposium on the organization, construction and operation of the Westchester County Sanitary Sewer Commission projects by W. W. Young, consulting engineer of the Commission, and his associates, under the following topics:

"Interurban Sanitation—Promotion, Legislation, Financing and Organization," by W. W. Young, Consulting Engineer.

"County Sanitary District Determination and Sewer Easement Acquisition," by F. J. Laverty, Project Engineer.

"Trunk Sewer and Tunnel Location, Pumping Plants, Specifications and Construction," by F. C. Zeigler, Project Engineer.

"Water Tightness in Sewers and How to Secure It," by E. C. Hallock, Chief Inspector.

"Fine Screening, Incineration and Sterilization Plant Construction and Features," by J. W. VanDenburg, Project Engineer.

"Plant Operation and Effluent Disposal by Dilution," by W. R. Schreiner, Bacteriologist and Chemist.

The papers were illustrated with lantern slides and were heard with intense interest.

William Johnson, baritone, delightfully entertained the group at dinner in the evening. Following a brief talk by I. W. Mendelsohn on "Sanitation in the Far East," the Round Table discussion was opened by Messrs. W. A. Hardenbergh, W. H. Larkin and G. A. Mowbray.

At the Round Table Breakfast Saturday, Morris M. Cohn and C. C. Agar conducted the Question Box. Under police escort the inspection trip was made in private cars to the Mamaroneck and the North Yonkers sewage treatment works and the Hutchinson pump station, all of the Westchester County Sanitary Sewer Commission.

It was announced that the Short School for sewage works operators would be conducted next April at Cornell University. A standing com-

mittee in research was appointed, having as its aim the stimulation and coördination of experimental and research work in sewage disposal at the various sewage treatment plants and universities in this state.

The next meeting of the association will be the Sixth Annual Meeting, to be held in New York City, January 16, 1934.

A. S. BEDELL, *Secretary-Treasurer*

The Fifteenth Iowa Sewage Treatment Conference and Seventh Annual Meeting Iowa Wastes Disposal Association

Iowa State College, Ames, Oct. 18, 19, 20, 1933

The Fifteenth Iowa Sewage Treatment Conference was held at the Iowa State College, Ames, on Wednesday, Thursday and Friday, October 18 to 20, 1933. A total of 83 municipal officials, engineers, superintendents and plant operators were in attendance. While this is a somewhat larger group than that of last year, the effect of the depression is still very evident.

The conference was in many ways the best of the fifteen such meetings held in Iowa. Present conditions in the sewage works field are unusual, particularly with regard to new public work, and the leaders took full advantage of the opportunity to help municipal officials with their problems.

The meeting was opened at 1:30 P.M. Wednesday with a brief welcome by Chairman Lindon J. Murphy, of the Engineering Extension Service, Iowa State College, Ames. This was followed by a talk on "Utilizing Existing Sewage Works to the Best Advantage" by A. H. Wieters of the State Department of Health. Mayor Edwin Manning of Ottumwa then gave an interesting description of the Ottumwa sewage works situation, explaining the relation of stream flow in the Des Moines River to water supply and sewage disposal conditions.

A troublesome problem of interest to many Iowa officials was well presented by C. C. McCarthy, of the City Engineering Department of Ames, in his paper on "Excessive Ground Water in a Sewer System and Its Effect on Sewage Plant Operation." The Wednesday meeting was closed by P. J. Houser of the State Board of Health with a talk on prechlorination of sewage for odor control.

On Thursday morning, C. H. Currie, Consulting Engineer and member of the Governor's Advisory Board of Public Works gave the opening address, speaking on "Opportunities and Limitations of Public Work Today." H. M. Cooper, chairman of the State Advisory Board of Public

Works, followed with a clear and straight-forward explanation of "How the Public Works Act Affects Your Town."

Mayor W. H. Stepanek of Cedar Rapids gave an interesting description of the steps taken in that city in starting a sewage works project under the Public Works Act. The morning program concluded with a discussion by P. F. Hopkins, State Engineer, Federal Emergency Administration of Public Works, on "How to Make Application for Aid on Municipal Sewerage and Sewage Treatment Works." This timely subject was covered in a very thorough and helpful manner. The round table discussion which followed brought out and cleared up a number of questions on specific details of the Public Works Act as applied to Iowa projects.

The Thursday afternoon program was also largely devoted to problems having to do with contemplated sewage works. Commissioner John McVicar of Des Moines spoke on "Sewage Treatment Studies Being Made by Des Moines." Howard R. Green, Consulting Engineer of Cedar Rapids, discussed the "Application of the Sewer Rental Law to New Construction."

"The Legal and Financial Aspects of Municipal Construction Under the Public Works Act" were then interestingly and fully presented by Attorney H. H. Stipp of Des Moines. A lively discussion followed on the interpretation of sections of the regulations pertaining to public works.

The technical program of the day concluded with a challenging paper on "Trickling Filter Ventilation" by Dr. Max Levine, Professor of Bacteriology at the Iowa State College. Painstaking research has brought into serious question many of the old accepted theories on filter ventilation.

On Thursday evening the Annual Banquet and Meeting of the Iowa Wastes Disposal Association was held. Following the dinner and entertainment an illustrated talk on "Sanitation in the Orient" was given by I. W. Mendelsohn, Consulting Engineer of New York. President Max Levine then called the members of the Association to order for the annual meeting. He gave a résumé of the activities of the Association and commented on the development and value of THE JOURNAL. The reports of the Secretary and Treasurer were then read, followed by the nomination and election of officers. The recommendations of the nominating committee were accepted and the following unanimously elected for the coming year: Earle L. Waterman, Iowa City, President; A. H. Wieters, Des Moines, Vice President; John W. Pray, Fort Dodge, and Elmer E. Dye, Mason City, Directors; Max Levine, Ames, and Lindon J. Murphy, Ames, representatives to the Board of Control. The executive board met at the close of the business session and reappointed the Secretary-Treasurer for the ensuing year.

On Friday the program was devoted to a practical operators school. Prof. Earle L. Waterman of the State University of Iowa presided at the

morning session and opened with a discussion on "Fundamentals of Sewage Treatment. Director Wieters, of the State Department of Health, followed with an analytical study of the theory of sewage sedimentation. Prof. W. E. Galligan then gave a clear explanation of the function of biological filtration. The theory and practice of sludge digestion was described in an understandable way by C. H. Currie, Consulting Engineer of Webster City.

A most interesting and practical talk was given by Supt. W. A. Sperry of the Aurora Sanitary District. His subject, "Observations on Sewage Works Operation" included many helpful suggestions both on the operation of the plant and of methods of securing public support and approval.

A round table discussion of operation problems participated in by the superintendents and operators opened the Friday afternoon session. Prof. Jack J. Hinman, Jr., of the State University of Iowa, then gave a timely and pointed talk on "Laboratory Control of Sewage Treatment Plants." He stressed the importance of full information in order to give significance to laboratory tests. The school closed with a laboratory demonstration of and instruction in sewage plant tests.

LINDON J. MURPHY, *Secretary-Treasurer*

Reviews and Abstracts

H. W. STREETER

The Middlesex Sewerage and Sewage Disposal Scheme

By John D. Watson

Résumé in *The Surveyor*, **84**, 339–40 (Oct. 20, 1933) of a Paper Presented at the London Meeting of the Royal Sanitary Institute, Oct. 17, 1933.

The western portion of Middlesex County, England, has been developing recently from a rural agricultural area into a rapidly growing, densely populated metropolitan district with large industrial plants.

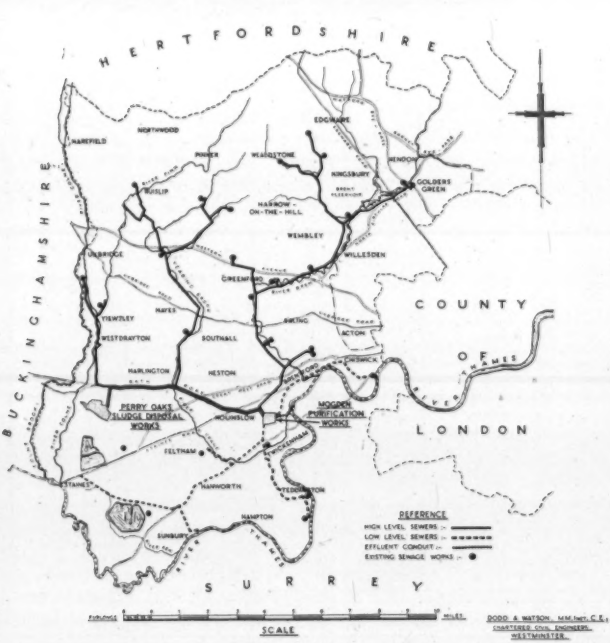
The West Middlesex drainage district, approximately 160 square miles in area, drains to the Thames above London through four streams, all of which, with one exception, have their sources within the area itself. These streams are consequently small and, in dry seasons, non-existent, thereby creating major problems of sewerage and sewage disposal. Two of them supply potable water to the reservoirs of the London Metropolitan Water Board.

The area includes the complete districts of twenty local governing authorities and had a population in 1921 of 493,000 which had increased to 771,000 in 1931 and in 1933 is estimated to be 860,000. A total of 27 public sewage treatment plants serve this area, 5 of which are located on the drainage basin of the potable water supplies above mentioned. Although the volume of sewage effluent was not great, serious difficulties were developing with the rapid population growth, multiplicity of governmental units and lack of dilution facilities of existing streams. Accordingly, a comprehensive drainage and sewage disposal scheme was designed and is now being constructed.

A total ultimate population of 2,000,000 is being provided for, equivalent to 80 m. g. d. of dry weather sewage flow and 480 m. g. d. of storm flow. Construction of portions of the purification works not immediately required for this ultimate load are not being provided at present although the sewerage system is being built complete. An estimated population in 1936 of 1,000,000 people, equivalent to 40 m. g. d. of dry weather flow and 240 m. g. d. of wet weather flow, will be served by the treatment works now under construction.

Sewerage System.—The sewerage system will consist of 67 miles of main intercepting sewers, ranging in size from 21 inches to 12 ft. 9 in. in diameter, 21 miles of which are being laid in open trench and 46 miles in tunnel. Cast iron or Ciment Fondu concrete pipes are being used gener-

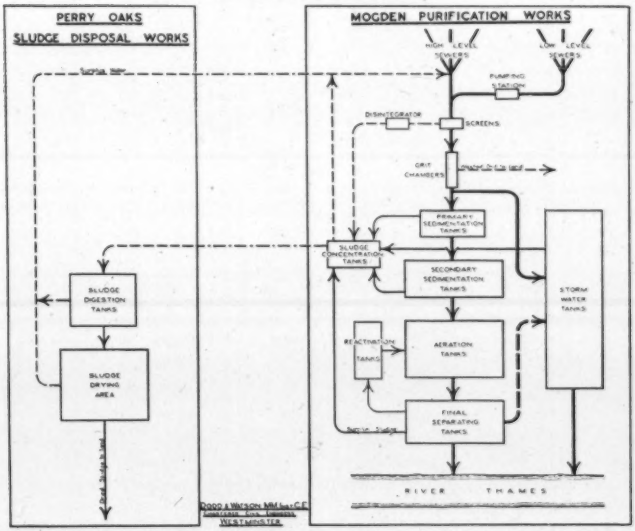
ally for sizes up to 3 ft. 9 in. in diameter, whereas larger sizes will be of brick, concrete, concrete segments or cast iron segments, in every case lined with best brickwork. To provide efficient ventilation, fresh air inlets are to be spaced not over 80 yards apart. These interceptors will convey the sewage to one central treatment works at Mogden. About



three-fourths of the total sewage volume will flow by gravity and the remainder will gravitate through low level sewers driven in tunnel to a pump well and there lifted 50 feet to be treated with that from the high level sewers. The low level sewers range in size from 3 ft. to 7 ft. in diameter.

Purification Works.—The site of the purification works at Mogden comprises a present area of 150 acres, sufficient for the plant ultimately required, including ample margins for encircling embankments and trees. The ultimate character of the sewage to be treated can only be estimated although based on the sewage of existing works it seems probable that the West Middlesex sewage will be of high average strength according to Ministry of Health standards. Because a high standard of effluent will

— MIDDLESEX COUNTY COUNCIL —
— WEST MIDDLESEX SEWAGE DISPOSAL —
— DIAGRAM ILLUSTRATING PROPOSED —
— METHOD OF PURIFICATION —



be required, the activated-sludge process has been selected for the main work of purification, for the reason that this method is adaptable to changing conditions and can be readily extended to meet industrial and residential developments. This plant will supersede all the existing plants in the drainage area. The treated effluent is to be discharged into the tidal waters of the Thames at Isleworth Ait, about four miles below Teddington Weir and about three-fourths of a mile from the works, through

two 11-ft. diameter conduits. Dispersion will be effected through 12 outlet pipes spaced 30 yards apart along the length of the river channel and which will rise vertically, terminating in the river bed.

Sludge Disposal.—An area of 223 acres of land at Perry Oaks, seven miles from the Mogden purification works, has been acquired for sludge disposal. The sludge will be pumped through a rising main to the sludge disposal plant and there completely digested and dried, particular attention being paid to the avoidance of smell and other objectionable characteristics of sewage works. Recovery of by-products such as fertilizer and gas will be of secondary consideration to that of nuisance elimination. Contamination of the underground waters about the site of the sludge disposal area is to be prevented by the construction of puddle wall trenches encircling the 150 acres used for sludge treatment and carried down through the pervious gravel and keyed into the London clay. All sludge liquor seeping into the ground inside this area will be drained by a sewer into one of the raw sewage interceptors and thus be returned to the Mogden treatment works. These precautions are deemed necessary to protect the ground waters of the streams used for the London water supply.

Costs.—Contracts for sewerage and disposal totaling £3,250,000, or about 70 per cent of the total estimated cost of the scheme, have been let. Work has been progressing rapidly on both the sewerage and treatment works during the past two years and it is anticipated that the project will be completed within the four-year limit originally set.

J. K. Hoskins

Sewage Treatment and Disposal

Papers and Discussion at the British Association Meeting at Leicester. Résumé in *The Surveyor*, **84**, 247–50 (Sept. 22, 1933)

At its meeting in Leicester the Engineering Section of the British Association devoted one morning session to a discussion of sewage treatment and disposal, the subject being introduced by Mr. J. D. Watson.

Mr. Watson reviewed the great progress in water supply and sewage treatment procedures, with particular reference to the Birmingham situation, where the death rate has been reduced from 23 per thousand to 10 per thousand during the past 60 years. Credit is due both public authorities and equipment manufacturers for costly pioneering in untried procedures and plant from which have been developed new methods of sewage treatment as exemplified by Birmingham and Sheffield. Bio-aeration, sludge digestion and the use of sludge gas for power are mentioned as specific contributions. Mr. Watson also suggested the consolidation of smaller sewage treatment plants into larger units for more efficient conservation of pure streams.

The Legal Aspect of River Pollution with Special Reference to the Rivers Pollution Prevention Acts was the subject of a paper by H. F. Atter of the West Riding of Yorkshire Rivers Board. The author concludes that lack of enforcement is in large part responsible for the present unsatisfactory condition of many rivers rather than deficiencies in existing law.

Aerobic Purification of Sewage by Natural Processes was discussed by Professor W. E. Adeney and Dr. A. G. G. Leonard. The results of their laboratory experimentation have demonstrated the fundamental principle that in the presence of dissolved oxygen equal volumes of the same polluted water undergoing aerobic fermentation consume equal quantities of oxygen and give rise to products which are constant in quantity. Rates of solution of oxygen and nitrogen in fresh and salt water have been determined and mathematically expressed. The "streaming" effect of dissolved gases from the exposed surface layer is given as the explanation of aeration throughout any body of water to depths of at least 10 feet.

The Bio-Aeration Method of Sewage Treatment as developed and applied at Sheffield was described by Mr. John Haworth. A new method of circulating the sewage around the channels for the purpose of aeration has been devised, in which the paddle wheels used in the former installations are replaced by a single pump, the channel floor being graded to produce proper circulation through the system to the pump intake. Advantages are simplification and increased efficiency of machinery, constant load and ease of sludge return. A plant at Sheffield using this new method of circulation is briefly described.

A modification or abbreviation of the bio-aeration process as employed at Birmingham results in greatly increasing the capacity of sprinkling filters for the partially aerated sewage liquor. However, it is necessary to recondition the activated sludge each time before reuse, a procedure not considered advantageous or economically efficient where existing filters are not to be considered.

Natural purification agencies, allied to activated-sludge methods, such as the dilution procedures being undertaken in the River Ruhr through impounding of the raw sewage in large lakes or at Bradford where the filter effluent is stored for prolonged periods are noted as interesting developments.

The Treatment and Utilization of Sludge was the subject of a paper by Mr. Frank C. Vokes in which the Birmingham method of sludge digestion was described. Sludge is separated from the sewage and conducted to separate digestion tanks as soon as possible. Digestion proceeds in two stages, the sludge being retained in the primary tanks only during active fermentation and gas production and then being transferred to secondary tanks for settlement and consolidation. After decantation of the surplus

water the sludge is pumped to drying beds and later removed for fertilizer. The collected gas is utilized for power production totaling 950 hp. at the Saltley Works and for heating sludge at the Yardley Works.

Machinery for dealing with sewage was discussed by Mr. H. R. Lupton. A type of "unchokeable" pump with impeller blades of rubber or other flexible material which will permit the passage of larger objects was described. Chain type rakes, moving screens and disintegrators, aeration apparatus, sprinklers, percolating filters, agitators, surface aeration mechanisms and other miscellaneous devices were outlined.

Discussion.—Mr. H. C. Whitehead of Birmingham discussed the objection to reused water by the English and pointed out that in fact in London, Worcester, Cheltenham, etc., much of the water supplied had been used before. Objections to reused water for water supplies had been definitely overcome in the United States and in Germany, especially for industrial purposes, and in the near future such reuse would likely increase in England. Dr. H. T. Calvert of the Ministry of Health disapproved of the Engineers' attitude against the reuse of water.

Mr. A. T. Gooseman of Leicester described a new method of disposing of screenings from the sewage works, where this material is discharged to a digester and cooked for from six to eight hours. The cooked material is a valuable manure free from all nuisance.

Mr. F. R. O'Shaughnessy of Birmingham noted the trend toward mechanical filtration of sewage and sludge incineration in America. He disagreed with the views of Professor Adeney and Dr. Leonard that the humus in separate digestion tanks in the digestion process plays a substantial part in odor prevention, preferring the explanation that anaerobic digestion effects bio-chemical changes entirely different from those resulting from natural processes. He believes also that aerobic digestion does not proceed in two separate stages but as a continuous reaction, in the early stages of which there is a rapid elimination of non-nitrogenous material. There is considerable evidence in fact to the effect that the nitrogen acts as a catalyst which takes up oxygen and transfers it from the atmosphere and water to the non-nitrogenous material.

Professor F. G. Baily pointed to a weakness in the Rivers Act of 1876 in that the local authorities, the only ones empowered to enforce its provisions, are largely composed of offending manufacturers. As a result some rivers and lakes in Scotland are in a deplorable sanitary condition.

Mr. F. T. K. Pentelow of the Ministry of Agriculture opposed the view of Mr. Watson that sewage treatment should be concentrated in large plants rather than in a larger number of smaller works. Concentration of large volumes of treated effluent in streams prevented the full benefits of dilution obtained by discharges from multiple, well distributed outlets.

J. K. HOSKINS

A Study of the Pollution and Natural Purification of the Upper Mississippi River

BY H. R. CROHURST

Public Health Bulletin, No. **203,** 113 pp. (*Public Health Eng. Abs.*, **13** (Apr. 1, 1933))

An outline of the methods used in collecting and analyzing the field data to study the effect of pollution from the Minneapolis-St. Paul metropolitan area and the changes due to natural purification phenomena in the upper Mississippi River below the Twin Cities.

The maximum effect of pollution was about 15 hours' flow below the sewers, a result in agreement with previous stream pollution investigations. The effect on re-aeration of the ice cover during the winter period was clearly indicated, the point of minimum dissolved oxygen occurring farther down-stream in winter than in summer. This fact suggests that in streams having long periods of ice cover, critical oxygen conditions may occur in winter rather than in summer. The effect of sewage and wastes within the zone of pollution was indicated by the biological oxygen demand test, but in the lower section of the stream, and in the absence of additional pollution, a marked increase in oxygen demand and bacteria occurred at times, suggesting a disturbance in the biological balance probably due to dilution from tributary inflow. This phenomenon has been observed in other water courses. Lake Pepin, an expansion of the river 50 miles below the sewers, through which the flow is exceedingly slow, exerts a marked influence on the recovery in oxygen balance and bacterial reduction. In the relatively short free-flowing section of the river above the lake, where channel conditions are comparable with other rivers, rates of bacterial decrease in the upper Mississippi River appear to be intermediate between the rates observed in the upper and lower Illinois River and greater than those observed in the Ohio River. Summer rates of bacterial decrease are from one to four times the winter rates, showing, as in the case of other streams investigated, the effect of seasonal temperature on rates of natural purification.

H. R. CROHURST

An Investigation of Conditions Resulting from the Present Method of Disposing of Sewage from the District of Columbia in the Potomac River

U. S. Public Health Service, *Document* No. **172,** U. S. Senate, 65 pp. (*Public Health Eng. Abs.*, **13** (Apr. 1, 1933))

A report to the Senate presenting the data collected during a study of the effect of Washington sewage on the Potomac River made during the period July 25–September 15, 1932.

In response to the specific questions propounded in the Senate resolution ordering the study, the investigation indicated that: In the summer months the concentration of bacteria in the entire river system around Washington, as far down-stream as Fort Foote, is such that the water is unsafe for bathing and constitutes a menace to public health from the standpoint of contracting sewage-borne diseases if bathing is permitted. Below Hallowing Point, sewage from Washington has no sanitary significance during the summer months of decreased run-off when the water is used for bathing and other recreational purposes.

Between Fort Foote and Hallowing Point there is a questionable zone, the extent of pollution depending upon times of flow from the sewers. From below the sewer outlets to above Hains Point, and in the Anacostia River to the District Line, there is a zone in which the dissolved oxygen is reduced, during summer periods of decreased run-off, to an extent approaching critical conditions. With normal increases in population and additional sewage load, critical conditions will occur more frequently and be of longer duration, and with complete exhaustion will create odor nuisances and be objectionable to residents along the river and to persons using the park facilities. For a considerable distance below the sewer outlet the amount of dissolved oxygen was below that required to support fish life, but below Fort Foote it appeared sufficient at all times to support the various requirements of fish life. The first oyster areas are 70 miles below Washington and probably are not affected by the discharge of sewage except during periods of exceptional floods; and even under such conditions it seems doubtful if the contamination reaching this section of the Potomac would be sufficient to affect the oysters for human consumption.

The report outlines possible methods of sewage treatment, should it be deemed necessary to preserve the river for recreational purposes, there being no question of water supply involved, and suggests the method of procedure for the design and construction of suitable works.

H. R. CROHURST

The Sewerage System of Tokyo

BY ISADOR W. MENDELSOHN

Public Works, **64**, 27 (September, 1933)

Construction of a modern sewerage system in Tokyo was begun in 1911, is about half completed and is expected to be finished in 1939 at a total cost of 70,000,000 yen (about $35,000,000). The sewers are mostly of the combined type and are designed to carry half of the estimated 45 gallons of sewage per capita per day in eight hours and run off at a maximum rate of 2 in. of rainfall in one hour. Vitrified sewers are used for sizes less than

18 in., precast reinforced concrete from 18 in. to 54 in. and field cast concrete shapes for sizes above 54 in.

Topographical conditions require 3 drainage districts. District No. 1 has 2 levels of gravity flow sewers and one level which requires pumping. The sewage passes through a 3 in. bar screen into two grit chambers with 1½ in. mechanically raked screens. The two plain sedimentation basins are operated on the fill-and-draw principle and are protected from tide water by regulating gates. Three 150 ft. square by 12 ft. sidewater depth, mechanically cleaned clarifiers are being built, together with storage tanks and pump capacity of 3 times the dry weather flow in order to pump only at low tide. An additional sludge storage tank is being provided. Excess storm water is by-passed.

The sewage from District No. 2 is intercepted and carried to the Mikawashima plant completed in 1921 at a cost of 4,480,000 yen, exclusive of pumping equipment. This plant handles 19 m. g. d. dry weather flow in winter and 26 m. g. d. in summer. The works consist of two sets of grit chambers and screens; pumping equipment with a capacity of "74,000 gals. per hour" for a 28 ft. lift; five sedimentation tanks with a combined capacity of 4.4 m. g.; 14 rectangular trickling filters with motor driven distributors covering an area of 308,000 square feet with 5.65 ft. of ½ in. to 3½-in. stone; two humus tanks and two sludge storage tanks of 36,000 cu. ft. capacity each. Fine wire screens 18 ft. high are used around the plant to prevent *psychoda* nuisance.

Drainage District No. 3 has 3 pumping stations and at the Sunamachi treatment plant the sewage is settled in 4 tanks with a capacity of 11.5 m. g. and held in storage reservoirs for discharge at ebb tide into the sea. The dry weather flow in this district is 34.5 m. g. d. Sludge from all plants is barged to sea.

Where sewers are not available private collectors gather the night soil at a cost to the householder of 1 yen per month. It is spread over land for fertilizer.

Experiments are being conducted with a Sheffield-paddle type of activated-sludge plant of 1.2 m. g. d. capacity and a diffused air plant of 0.037 m. g. d. capacity. In the mechanical agitation process decreasing the length of the circulation channels with a reduction of 78 per cent in the volume of the aeration tank and shortening the period of aeration from 20 hours to 5, reduced the power consumed by ⅓ without any appreciable effect on the percentages of purification. Preliminary sedimentation of the sewage from four to six hours before activated-sludge treatment had no favorable effect on the final result. When part of the activated sludge in the mixed liquid was allowed to settle in the bottom of the aeration tank, the decomposition of the sludge proceeded without any appreciable inter-

ference to aeration, thereby decreasing the excess sludge to a considerable extent. ROBERT W. KEHR

Studies of the Pollution and Natural Purification of Streams. IV. A Resurvey of the Ohio River Between Cincinnati, Ohio, and Louisville, Ky., with a Discussion of the Changes Since 1914–16 and the Effects of Canalization

BY H. R. CROHURST

U. S. Public Health Service, *Public Health Bulletin* **204**, 111 pp. (1933) (Summary in *Public Health Reports*, **48**, 32, 976–9).

From November, 1929, to May, 1931, the U. S. Public Health Service, in coöperation with the Kentucky State Board of Health and the Louisville Sewerage Commission, made a sanitary survey of the Ohio River between Cincinnati and Louisville to determine the changes in sanitary conditions since a previous survey in 1914–16 and to study the effects of canalization of the river on natural stream purification. The study included laboratory examination of nearly 2000 samples of river water, the tabulation of stream discharge, estimates of times of flow and a survey of sources of pollution, including total and sewered populations and waste-producing industries.

Changes affecting the sanitary status of the river in the Cincinnati-Louisville stretch since the 1914–16 survey include construction of 2 additional dams, making 4 now between the two cities; an increase of 8 ft. in elevation of the dam at Louisville; an increase in total population of 1,227,000 above Cincinnati and of 433,000 between the two cities; an increase of 212,000 in sewered population within the zone of investigation, making a total of 890,000 contributing untreated sewage to this section of the river; and a possible decrease in industrial waste pollution due to elimination of brewing and distilling and curtailed activity of other industries.

A study of the data collected has indicated that under comparable conditions of winter flow, the dissolved oxygen content of the river was about the same as in 1914–16, the B. O. D. about one-half and the bacterial pollution somewhat higher. Under summer conditions of pool stage, both the D. O. and B. O. D. were less than in 1914–16, but the ratio of available to required oxygen was roughly the same for the two periods. During the summer of 1930, when the drought caused a low discharge of 2000 second-feet at Cincinnati, the D. O. content of the Ohio was completely exhausted below Cincinnati. At the Cincinnati and Louisville water intakes the

quality of the raw water was sufficiently good to permit the production of effluents meeting the Treasury Department drinking water standard, with the highly elaborated treatment and efficient operation in force at both filtration plants. The removal of turbidity in the river pools resulted in increased numbers of microscopic plants in the river water and consequently shortened filter runs and taste and odor troubles in the plant effluents.

The summer and winter rates of bacterial purification below Cincinnati were quite similar in 1929–30, as were also the 1929–30 and 1914–16 winter rates under comparable stream conditions. During the extremely low water of the summer of 1930, rates of bacterial decrease were less than in the summers of 1914–16, possibly due to the lowered bacterial concentrations resulting from the decreased velocities of flow below Cincinnati and to changes in the condition and types of organisms present after the longer periods of flow. At times of unobstructed flow a secondary increase in bacterial content of the river was noted below the mouth of the Great Miami River, suggesting the disturbing effect of dilution from this tributary on biological balance of the main stream.

Canalization, resulting in diminished velocities of flow in the river pools, permits sedimentation of sewage solids, with resulting decrease in dissolved oxygen and possible creation of nuisances in the vicinity of sewer outlets rather than at further distances down-stream. Though reduced bacterial loads on water purification plants make production of safe effluents less difficult, increased numbers of microscopic organisms, resulting in shortened filter runs and taste and odor troubles, more than offset this advantage. The concentration of decomposition products due to fermentation of organic deposits within the pools may have public health aspects not hitherto appreciated. Reference is made to the suspected water-borne outbreak of gastroenteritis along the Ohio River during and following the low flows in the fall and winter of 1930–31. Canalization, at least between Cincinnati and Louisville, seems to have had the tendency to complicate, rather than simplify, the problems connected with sewage disposal, nuisance production, operation of water-treatment plants and the preservation of public health.

H. W. STREETER

Non-Odorous, Non-Bacterial Sewage Treatment

ANON.

Public Works, **64**, 10 (September, 1933)

A chemical treatment process, developed by A. R. Putnam, Sanitary Engineer of Valparaiso, Ind., during the last four and one-half years, has been used experimentally to treat the sewage from a population of 700 people.

The experimental plant occupied a space 14 × 16 ft. and was located in a thickly populated district without nuisance.

The sewage first receives 3 to 6 grains per gallon of activated carbon, depending on its freshness, then lime and ferric chloride (1.5 grains per gallon of ferric chloride at Valparaiso), are mixed, and then settled in an upward flow, mechanically cleaned tank. The effluent from the sedimentation tank is sterilized, filtered, if necessary, through $^1/_2$ inch of carbon supported on 16 in. of sand, and discharged without further treatment.

The sludge is dewatered, dried in retorts in 3 stages, 70°, 100°, and 400° C., the latter converting the ferric hydroxide to oxide. After being pulverized about 5 per cent is applied to the sewage prior to mixing until the build-up of mineral matter decreases its efficiency, when a fresh start should be made. "The charred sludge not used in the process can be used commercially."

The vapor from the retorts is condensed and those gases not absorbed by water are returned to the retort furnaces as an auxiliary fuel. The condensed vapor has been found to be "an excellent fertilizer and also an exterminator of bugs, worms, scale, etc."

The cost of the plant is estimated at $204,000 for a 9 m. g. d. plant and operating expenses are estimated at $22.60 per m. g. for a 3 m. g. d. plant exclusive of interest or depreciation. ROBERT W. KEHR

Disintegrating Sewage for Ocean Dilution

ANON.

Public Works, **64**, 22 (September, 1933)

To eliminate or lessen fouling of beaches, the city of Bournemouth England, has installed disintegrators to disintegrate the solids on each of 5 outfalls which collectively discharge 6 m. g. d. of sewage 2000 feet beyond high water into water 40 ft. deep. The disintegrators are 8 in., 12 in., 15 in. and 18 in. in diameter. They consist of a case-hardened impeller rotating between a fixed steel blade and a set of guide vanes, both of which cut with a scissors or shearing action. The sewage is first screened in metal baskets, cleaned daily to prevent damage by stones, etc., to the blades. Storm waters are screened and bypassed directly to the outfall, most of the solids being retained on the screens for passage through the disintegrator. The two smaller units are powered by variable speed d. c. motors controlled by a float in the suction sump, as the rotating blades act as centrifugal pumps. The cost of the units complete varied from £600 to £800.

The greatest advantage of disintegrating sewage solids is in hastening natural purification processes. No fouling of the beaches now occurs

from the outfalls, and sea-gulls which formerly resorted to the outfalls, have disappeared. ROBERT W. KEHR

Cast Iron for Sewer Connections in Maryland

ANON.

Public Works, **64**, 20 (September, 1933)

Observations during 14 years of sewer construction, covering 160 miles of sewers with 8700 house connections, have led to the conclusion that the use of cast iron connections from the house, or property line, to the sewer are more satisfactory than other types of pipe commonly used for this purpose. ROBERT W. KEHR

Sludge Disposal by Incineration

BY M. J. BLEW

Public Works, **64**, 39–40 (August, 1933)

The many advantages of the disposal of sludge by incineration include saving in capital cost through elimination of sludge drying beds; elimination of digestion tanks when fresh sludge is incinerated; elimination of nuisance; reduction in volume of resulting waste to be handled and less space required for an installation.

The calorific value of sludge varies with its combustible content. Sludge from separate sewer systems is higher in heat content than that from combined systems. In the latter the sludge deposited after storms is lower in heat value than that produced by dry weather flows, because of the large amount of grit or other inert material carried in storm water. Sludge produced by activated-sludge plants is also high in heat value.

THERMAL DATA ON SLUDGES

Source	B. t. u. per Pound of Dry Solids
Fresh sludge (combined system)	6380
Imhoff sludge, combined systems, sand beds	3500
Fresh domestic sludge, Lakewood, N. J.	9000
Domestic sludge from sand beds	6000
Scum, separate digestion tank	6800 to 9000
Secondary tank sludge, Plainfield, N. J.	7500
Domestic sludge, separate digestion	7500
Imhoff tank sludge, Philadelphia	4686
Detritus from grit channel	1900 to 3400
Fresh sludge Palmyra, N. J.	9100
Scum	9600

Fine screenings, drained, contain 2000–3000 B. t. u. per pound. Coarse screenings may run above or below these figures, due to such factors as the size and maintenance of the screen, etc. Scum from settling tanks contains soap and grease and has a high heat content, several samples having shown values from 8500 to 9000 B. t. u. per pound of dry solids.

Moisture Content and Temperature.—Under the most favorable conditions, sludge with a moisture content of 75 per cent has been found to be self-sustaining; it is, therefore, desirable to dewater to this point or, preferably, lower.

To prevent odors incineration must be carried on at temperatures above 1400° F. and preferably up to 1800° F. Clinkers are produced when much sand is present in the sludge at heats greater than 2000° F. Ordinarily at temperatures of 1400° F. the ash is of a red-brown color and very fine, 95 per cent of it passing a 200-mesh screen. It contains from 0.5 per cent to 4 per cent volatile matter when the grates are properly operated.

Incineration.—The plant should be so arranged that the storage period for sludge is as short as possible. The sludge should be dewatered and predried before reaching the combustion chamber, and combustion should be complete in a refractory lined chamber. The removal of ash and clinker should be automatic. A secondary combustion chamber should be provided to finish the destruction of the gases from the drying chamber. Forced draft should be available and it is desirable to have the air preheated to 300 or 400 degrees. Special provisions should be made to admit the wet sludge so as not to blanket the fire. C. T. WRIGHT

Trade Wastes and Sewage Treatment

Public Works, **64**, 31–2 (August, 1933)

Information concerning troubles in sewage treatment plants due to various trade wastes was recently obtained through a number of city engineers. One question had to do specifically with the effect of laundry wastes on treatment plants. In all, troubles of greater or less degree from this cause were reported by 19 cities. In some cases it was the combination of these and other trade wastes that caused trouble.

Foaming of tanks, excessive amounts of grease and soap, failure to clarify, boiling of tanks and septic action in tanks were among the causes listed as being due chiefly to the presence of laundry wastes.

Difficulties due to trade wastes were reported by 93 cities, or about 10 per cent of those reporting. The following causes of trouble were listed: alcohol wastes 2; cannery wastes 6; garage, filling station wastes and miscellaneous oils 24; wool wastes 2; creameries 9; oil from factories 4;

pickling plants 2; oil refineries 2; apple acids 1; steel mills 1; packing plants 5; dry cleaners 3; tanneries 1; hosiery and knitting mills 2; rubber packing wastes 1; malt wastes 1 and produce plants 1.

Perhaps the most unexpected major source of trouble was due to creamery and milk wastes. It is believed that milk wastes are an important factor in preventing satisfactory operation in a number of small sewage plants.

Some experimental work is now being carried on with laundry waste treatment, the results of which will appear in a later edition of *Public Works*.

C. T. WRIGHT

Assessing for Storm Sewers

BY C. V. DAVIS

Public Works, **64**, 21-2 (August, 1933)

Four systems of storm sewers had been built by Roselle, N. J., in the period 1926 to 1929 at a total cost of $165,431. The assessment of property for the cost of the sewers gave rise to vigorous opposition by property owners, resulting in the employment of consulting engineers to report upon the subject.

Study of legal decisions indicated that special benefits may be measured legally in two ways: (1) The difference in the market values of the property before and immediately after the construction of the improvement. (2) The fair cost of an improvement that a reasonable owner would make at his own expense in order to obtain the same benefits that would result from the construction of the improvement.

Tangible Special Benefits.—Properties adjacent to the sewer or to the natural stream which the sewer replaces, receive special benefits of a tangible nature. These are:

1. *Service Benefits.*—The value of the provision for drainage that a property owner would have to make in order to obtain benefits equivalent to those afforded by a storm sewer abutting his property. As a 12-in. or 15-in. pipe in the street would give such drainage, half the cost of this for a length equal to the frontage of his lot was taken as the measure of such benefit. The average of the costs of such a sewer in several cities was found to be $1.36 a foot, and half of this, or 68¢ per front foot, was used in calculating service benefits.

2. *Flood Relief Benefits.*—Obtained through the removal of flood waters from the land adjacent to the natural stream. Such benefit is taken as the expenditure that the property owner would have to make in raising the land above flood level and confining the stream to a narrow channel, to obtain flood relief equivalent to that provided by the storm sewer.

The cost of the fill comprising this hypothetical improvement was taken as 35.9¢ per cubic yard, the average of costs in eight cities in 1927 and 1928.

3. *Land Reclamation Benefits.*—The development value of land adjacent to a stream will vary inversely as the frequency with which the land is flooded; land flooded 90 per cent of the time has little value. If flooding is prevented by filling in, the value of this reclamation may be estimated as equal to the minimum difference between the value of the land prior to reclamation and the normal value after reclamation; and the minimum value of this may be taken as the cost of such reclamation by filling the flooded area. There is usually additional appreciation due to intangible human factors but these are not always a fair measure of value and are not used in the assessment determination.

Removing flood waters by a sewer effects similar reclamation and confers similar benefit. In addition, it restores the stream bed itself to a value equal to that of the land adjacent to it. This value may be taken to vary with the location of the stream. If it flows across the property from front to rear, the value of the land reclaimed will be the width times the front foot value of the land. If it flows parallel to the front line, the value will decrease with its distance from the front. In this calculation the land is divided into four strips and that in front given 40 per cent of the value of the entire property, the next strip 30 per cent, the next 20 per cent and the rear strip 10 per cent. After studying property values in the improved sections, $25.00 was taken as a fair front foot value for use in stream reclamation.

C. T. WRIGHT

Organization, Plans and Publications of the German Sewage Works Association

BY DR. ING. HEILMANN

The publishing firm of R. Oldenbourg, of Munich, has recently issued a bulletin describing the organization of the German Sewage Works Association, giving an outline of the assignments to various committees, and including several original papers on technical topics pertaining to sewage disposal.

The German group was organized more than two years ago, as a subgroup of the German Association for Construction (Deutschen Gesellschaft für Bauwesen). A notice of this organization appeared in THIS JOURNAL in April, 1931, page 292. At present the group has approximately 200 members. *Gesundheits-Ingenieure* has been selected as the official publication. Most of the material in the Oldenbourg bulletin

has been published in *Gesundheits-Ingenieure*. The various articles and proceedings have been assembled by Prof. Heilmann of Halle.

A very ambitious program has been outlined, with assignment of topics to four leading German engineers. These topics and chairmen are as follows:

1. Sewerage—Dr.-Ing. Trauer, Breslau
2. Sewage Treatment—(Chairman to be appointed)
3. Sewage Economics—Director Langbein, Berlin
4. Sewage Law—Prof. Knipping, Darmstadt
5. Status of Sewage Disposal—Dr.-Ing. Heilmann, Halle

The bulletin contains preliminary reports on all of these topics. Drs. Reichle and Weldert, of the Prussian Institute for Water, Soil and Air Research, have collaborated in outlines of suggested reports on stream pollution. Dr. Heilmann offers a detailed description of operation of the Halle heated digestion tanks. Four long and detailed articles discuss the use of concrete in sewer construction.

A very ambitious program of reports and publications has been planned, and the names of the sponsors, such as Langbein, Heilmann, Imhoff, Prüss, Bach, Reichle, Weldert, Spitta, Thumm, Olszewski and Mahr, among others, indicate that authoritative monographs will appear. A great loss has recently been sustained by the death of Dr.-Ing. Helbing, of the Emscher District, one of the leading and best-known engineers in Germany.

The further contributions from the group will be of interest. This first report is equal to a fair-sized book, including 68 pages of 6 point type on pages $8^1/_2$ by 12 inches. It is sold by R. Oldenbourg, Gluckstrasse 8, Munich. The price is 3.50 marks. F. W. MOHLMAN

What is the SALVAGE VALUE of a Septic tank?

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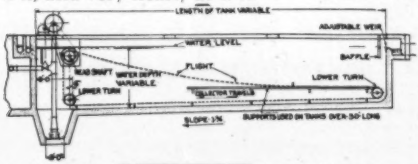

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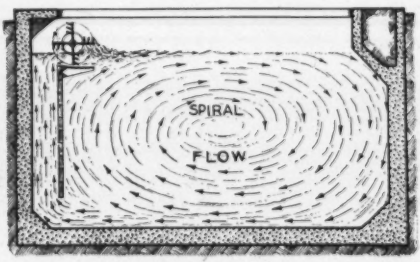

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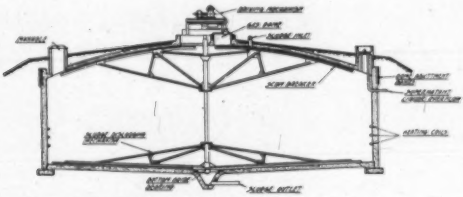

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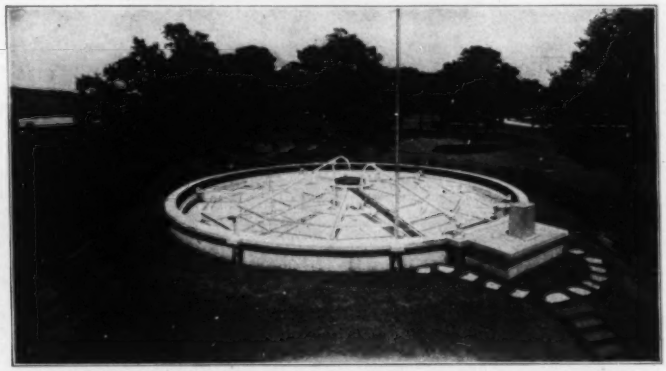

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Statement of the Ownership, Management, Circulation, etc., Required by the Act of Congress of August 24, 1912, of Sewage Works Journal, published bimonthly at Easton, Pa., for October 1, 1933.

State of New York }
County of New York } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William W. Buffum, who, having been duly sworn according to law, deposes and says that he is the Business Manager of the Sewage Works Journal and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business managers are:

Name of — Post Office Address

Publisher, Federation of Sewage Works Associations, c/o H. E. Moses, Pa. State Dept. of Health, Harrisburg, Pa.

Editor, F. W. Mohlman, 845 South Wabash Avenue, Chicago, Ill.

Managing Editor, F. W. Mohlman, 845 South Wabash Avenue, Chicago, Ill.

Business Manager, William W. Buffum, 654 Madison Avenue, New York, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

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3. That the known bondholders, mortgagees and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)

None.

4. That the two paragraphs next above, giving the names of the owners, stockholders and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association or corporation has any interest direct or indirect in the said stock, bonds or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is: (This information is required from daily publications only.)

WM. W. BUFFUM, Business Manager

Sworn to and subscribed before me this 20th day of September, 1933.

(Seal) THERESA A. KRAUS

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